Designing Personal Informatics Technologies for Meaningful Engagement with Experiences During Everyday Life

Thesis

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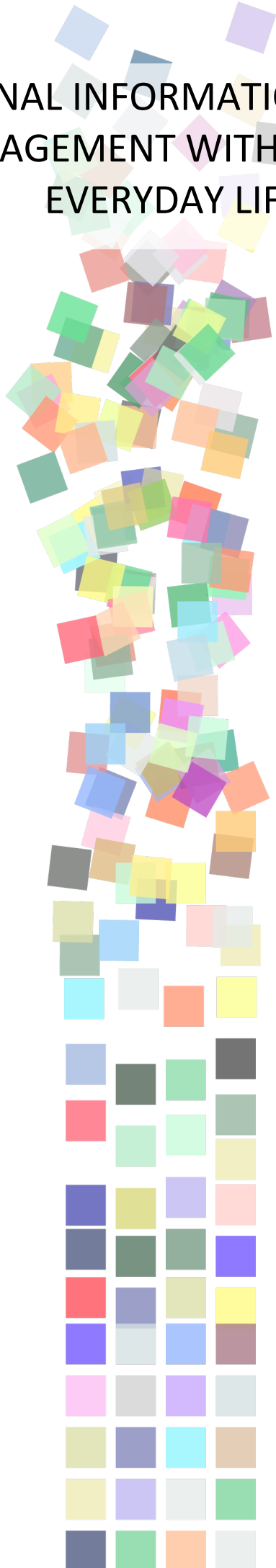

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Designing Personal Informatics Technologies for Meaningful Engagement with Experiences During Everyday Life

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Abstract

Responding to calls for more flexible personal informatics (PI) technologies, this thesis explores the design of *experiential logging* technologies, with which users can engage with the meaning of their subjective experiences during everyday life. The research it describes focused on questions concerning flexibility, minimalism and reflection in this context. It produced two prototypes to investigate these questions with users in the wild.

First, using a technological probe with the first prototype, *SpriteCatcher*, the research observed that users found value and meaning through the act of expressing their experiences through colour data. Further, it suggested the need to explore whether unstructured, expressive manual logging can prompt reflection-in-the-moment. This informed a second prototype, *Chromatize*, which supported three different minimalist logging methods. *Chromatize* was used in a larger-scale, 6-week longitudinal study to better understand how flexibility and minimalism support logging and reflection, and to characterise more precisely how users reflect when using such devices.

Together, the two studies showed that minimalist, highly flexible PI technology designs provide the means for users to dynamically engage with the aspects of life that are meaningful to them from moment to moment. The expressivity and directness of the logging interactions, and the simplicity and physical presence of the device affect when and how users engage. Drawing on substantial background literature about reflection, the thesis distinguishes between hard and soft reflection. It characterises how users might reflect when they use PI technologies, pointing to the significant role that soft reflection through manual logging can play. It concludes that the field of PI needs to expand its treatment of reflection, placing greater value on short-term, momentary day-to-day insights.

The thesis finishes with nine design considerations that distil broad insights from the research. These can inform the design of PI technologies for meaningful engagement with experiences during everyday life.

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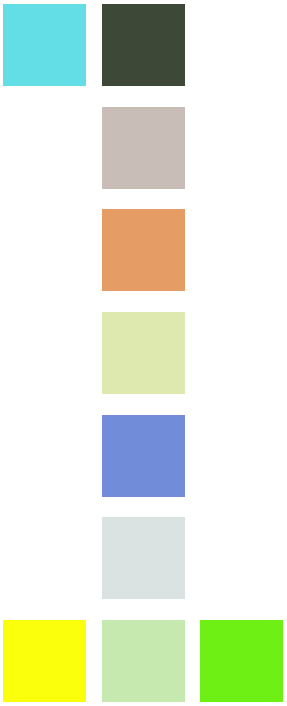


1. Introduction

The increasing ubiquity and range of personal informatics (PI) technologies, and the proliferation of HCI research on this topic, are signs of growing recognition for the potential of PI technologies. PI technologies are perceived as tools that can enhance the natural capacity that people have to reflect on their activities, by encouraging them to engage with information about their lives that they might otherwise overlook, or which might be inaccessible to them. Consequently, PI technologies have found utility in contexts where precise, consistently logged personal information is critical. Research has shown, for instance, that "self-tracking" apps can help with the everyday management of chronic health issues (MacLeod, Tang, and Carpendale 2013), such as diabetes (Mamykina et al. 2010) and multiple sclerosis (Ayobi et al. 2017). They have also found utility as activity trackers in contexts where they can automatically collect information which is beyond the grasp of the natural senses. Activity trackers such as *Fitbit* and exercise apps such as *Strava* use GPS and heart rate monitors for monitoring exercise, physical health and fitness.

These are valuable applications of PI technology. However, if we take personal informatics to be the study of technologies with which users can develop self-knowledge, they are also narrow applications. By targeting very specific activities or behaviours, they only provide limited scope for users to learn about themselves. The personal data logged with such devices says little about broader subjective experiences, which influence how it feels to be oneself in the world. This narrow approach to PI system design seems to have been propagated by a utilitarian theoretical underpinning in the PI field. Researchers have tended to focus on data about externally evidenced behaviours and activities because they perceive behavioural change, rather than self-knowledge, as the ultimate goal of PI systems (Rapp and Tirassa 2017).

Noting these limitations, some commentators have called for the design of PI systems which allow users to learn about their lives more broadly, taking into account their subjective experiences as well as their individual activities and behaviours (Elsden et al. 2016; Rapp and

Tirassa 2017). Given that so much of life is shaped by how our experiences feel to us as individuals, rather than how they are represented externally, this seems to be a valuable goal. Taking up this call, the research reported on in this thesis focuses on much broader and more open applications of PI technologies than have been typical in the field: *PI technologies for engagement with experiences during everyday life.*

Everyday life, which we define as an aspect of life that is interpreted by the individual, is not only an interesting context of focus because of its openness, but also because it could provide for rich applications of PI technologies. The personal data that users log and reflect on with PI technologies could help users to access the hidden significance in their lives that may usually go unnoticed. Given the routine repetitiveness and sameness of everyday life, people may have a tendency to go through everyday life without engaging with the qualities of their experiences. By providing users with personal data that can inform them about elements of their life which they don't engage with, there is an opportunity for PI technologies to help them to gain access to the hidden qualities and bring them into focus.

Given that this broad context hasn't received much attention in HCI, it isn't clear how we should be designing for it. The aim of this thesis is to explore how we can design PI technologies for experiential engagement during everyday life and what impact different design characteristics might have on the way users interact and engage with their experiences. There are many ways to address this problem and many different forms of design that could be the focus. The section that follows (1.1), sets out the research aims for the project, conveying which kinds of design we are focusing on, specifically, and which questions we are asking about them.

1.1 Research aims

The overall aim of the research can be stated as the following:

> *To explore how PI technologies can be designed so they support meaningful engagement with experiences during everyday life*

There are three main reasons why we have chosen to focus on the use of PI technologies in this context, which will now be described. In each case a research question is formulated to illustrate the sub-aims that serve this broader overall aim.

> ***RQ 1: How can we design for flexibility, such that users can freely engage with the experiences that matter to them in the way that they want to?***

Firstly, exploring how PI technologies might serve as tools for *meaningful engagement with experiences* provides an opportunity to implement an approach to PI technology-use that fits with the call for more focus on subjective experiences (Rapp and Tirassa 2017; Elsden et al. 2016) and contributes to the broadening of scope within PI. Given that subjective experiences are by their nature, personal to the individual, this focus requires that we build on emerging research on *flexible* PI technologies (Kim et al. 2017; Thudt et al. 2018; Ayobi et al. 2018), by investigating how systems can be designed so they let users engage with data about their experiences in the way that makes sense to them as individuals.

> ***RQ 2: How can minimalist interaction design support experiential logging during everyday life?***

Secondly, focusing on PI technology-use during *everyday life* provides an opportunity to investigate how we can design systems that make it simple for users to log and revisit data about their experiences. Research suggests that users can find it burdensome to use PI devices in the long term, particularly when they have to log and manage their data manually (Lazar et al. 2015; Harrison et al. 2015). And yet manual logging is important in the given research context, because this allows users to express their subjective experiences. It is important,

therefore, to examine how we can design PI systems for manual data logging that make it simple and easy for users to interact. Research has provided an indication that simple minimalist interaction designs for logging and revisiting data might help (Ferrario, et al. 2017; Choe et al. 2015). However, this research has been focused on logging specific aspects of experience in a limited way. A sub-aim of the research, therefore, is to address this issue and assess how minimalist interaction design can support experiential logging during everyday life.

> ***RQ 3: How do users reflect when they use experiential logging devices and what does this tell us about how reflection should be conceptualised within PI?***

Finally, the broad focus on meaningful experiential logging during everyday life provides an opportunity to develop our understanding of the different ways that users can *reflect* on their experiences. Reflection is a prominent topic in PI literature. However, it has been perceived narrowly within the field. Given that there has been a lot of focus on behaviour change as an end goal for PI technology use, transformative reflection through which users fundamentally change their perspectives on a given aspect of their life, has been the focus. In this project, by focusing on experiential engagement as a broad frame of reference, rather than behaviour change or self-knowledge development, we provide an open platform from which to probe some of the more subtle ways in which users might reflect on their experiences. The openness of the context allows for a broad consideration of how reflection with PI system should be conceptualised and the different ways that it manifests.

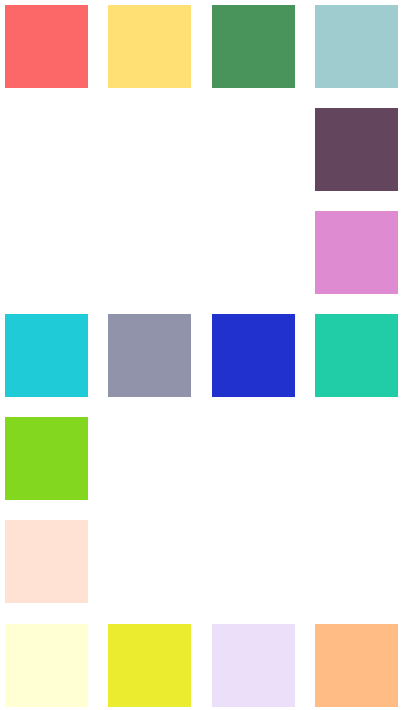
1.2 Thesis Structure

The structure of the thesis is as follows:

Chapter 2 is a literature review which introduces and presents previous work relating to flexibility and minimalist interaction design. Building on this review, **Chapter 3** describes an explorative user study, in which a prototype experiential logging device, *SpriteCatcher*, is implemented and used in an *in-the-wild* field trial. The results highlight how users engage with their experiences when they use an experiential logging device, and how different *flexible* and *minimalist* design characteristics appear to affect this. They also provide a preliminary indication of the role that reflection plays when users log data.

Chapter 4 is a literature review that illustrates how reflection has been interpreted inside and outside of the PI research field. Building on this review, **Chapter 5** describes an investigative user study, in which a prototype experiential logging device, *Chromatize,* is implemented and used in an *in-the-wild* field trial. The findings focus on logging behaviour, reflection and design characteristics, setting up the discussion that follows in the following chapter.

Chapter 6 provides a discussion of the findings from the study reported on in chapter 5. It sets the findings in the broader context of background literature and insights drawn from chapter 3 as a means to address the overall aim of the research – to understand *how to design PI technologies for meaningful engagement with experiences during everyday life*. **Chapter 7** then summarises nine key considerations for designing experiential logging devices, discusses avenues for future work and provides a conclusion to summarise the broad contribution of the thesis.



2. From the Quantified Self to Flexible, Minimalist PI Technologies: A Literature Review

The idea that the routine recording of personal information might support self-knowledge and, in turn, self-improvement extends back to the pre-digital age. Key figures in history have discussed the value of *the examined life*, including the ancient Greek philosophers and more recently, Benjamin Franklin, who used a 'virtue journal' - a table in which he would mark off 13 virtues each day with a dot (Shaw and Franklin 1982). The emergence of digital technology, and in particular mobile technologies in the last few decades has facilitated new ways of enacting these practices, and has led to wider recognition and discourse about Personal Informatics (PI) in research and more broadly in society

2.1 Tools for "self-knowledge through numbers"

Li et al.'s paper from 2010, in which they present their *stage-based model of PI* (Li, Dey, and Forlizzi 2010) appears to be the moment when PI was first brought into focus in HCI literature. They describe five stages of the process through which PI technologies are used, culminating in an action stage – (*Preparation– Collection – Integration – Reflection – Action*). The preparation stage is when users choose what data to record and how to record it; the collection stage is when they record the data, either manually or using the sensors of the device; the integration stage is when data is brought together and aggregated or transformed in some other way so it can be reflected on; the reflection stage is when users reflect on short-term or long-term data; the action stage is when users do something with their reflective insights and alter their behaviour in some way. Given the onus on preparation, reflection and action there is a clear relationship between this PI model and the *Transtheoretical Model of Behaviour Change* for healthcare; a parallel, which Li et al. acknowledge in a follow-up paper (Li, Dey, and Forlizzi 2011)

To develop their model, Li et al. carried out a survey to collect data about the attitudes of PI bloggers and members of the *quantified-self* movement – a pre-existing user group who were already passionate about data and had been discussing their personal data collection and analysis practices in show-and-tell events online. This approach of defining PI based on perspectives of people within the existing PI culture was continued in further work by Li et al. (Li, Dey, and Forlizzi 2012; 2011), and in key papers by Choe et al. (2014), Whooley et al. (2014) and Lupton et al. (2014).

This early PI literature emphasised the role of data as a source of self-knowledge, pointing to the quantified-self motto of "*self-knowledge through numbers*", (Lupton 2014; Choe et al. 2014; Whooley, Ploderer, and Gray 2014; Li, Dey, and Forlizzi 2010) and how numerical data is perceived as a "*superior form of knowledge*," which can "*replace the vagaries of intuition*." Additionally, it emphasised the power of digital automation; with automated sensing pictured as a way to make data collection easier and more convenient (Choe et al. 2014; Lupton 2014; Li, Dey, and Forlizzi 2010), and automated integration of multiple streams of data as a way for systems to deliver intelligent insights to users (Whooley, Ploderer, and Gray 2014; Li, Dey, and Forlizzi 2012).

2.2 Lived informatics

In general, early PI research has had a data-centric, technical focus, perhaps reflecting the technical focus of the quantified-self culture into which it was tapping. At this point there was little attention to the nuances of user experience and the range of needs and motivations driving the way users interact with PI technologies. Li et al.'s model typifies this by picturing users as being part of the data-interaction process rather than active agents directing it. Steps 1 -3, in which data is collected and prepared are pictured as machine-led processes, and steps 4-5, reflection and action are presented as inevitable consequences of exposure to data.

Users are more unpredictable and influential than this framing of interaction with PI systems suggests. This was brought to light in Rooksby et al.'s paper (2014) in which they introduce the concept of *Lived Informatics.* They analysed the practices of users of PI technologies, describing a range of different reasons why people track data and labelling five styles of tracking. Challenging the perception that PI system-use is driven by behaviour-change goals alone, they show that users have different goals and motivations and sometimes self-track out of curiosity or because they find it pleasurable to document their activities. They also highlight how PI technologies are used sporadically as motivations change over time, with users focusing on their ever-changing short-term needs, rather than fixed longer-term goals. Given that Rooksby et al. included participants in their study from outside the quantified-self culture, their insights represented the perspectives of a broader user group; people who may not be so comfortable and familiar with data as quantified selfers.

Lived Informatics framed a new agenda for PI research, bringing the nuances of user experience into closer focus as PI devices "*become enmeshed with everyday life*" (Rooksby et al. 2014) (p. 1163). HCI papers have subsequently focused on topics that reflect this shift in perspective, including why people engage with activity trackers (Gouveia, Karapanos, and Hassenzahl 2015), why they abandon them (Lazar et al. 2015), how they customise them (Harrison et al. 2015) and the different types of goals that users have when they are gathering information about themselves - including the formation of good habits (Gouveia, Karapanos, and Hassenzahl 2015), improving fitness (Gui et al. 2017), documenting activities (Elsden et al. 2017) and managing health problems (Lupton 2017).

Bringing together many strands of this work, a *model of Lived Informatics* has been proposed by Epstein et al. (2015). Unlike, Li et al.'s model, which characterised PI as a linear, stage-based process through which data is procedurally translated into human behaviour change, this dual level cyclical model characterises the unpredictability of users and their capacity to use PI technologies in a non-sequential structure. The model consists of two cyclical processes (Figure 1). The high-level cyclical process, which manifests when users are preparing to track, is split into four processes (*deciding, selecting, lapsing, resuming*). The lower-level cyclical process,

which functions once the user has started to track is split into four processes (*collection, reflection, integration, tracking and acting*).

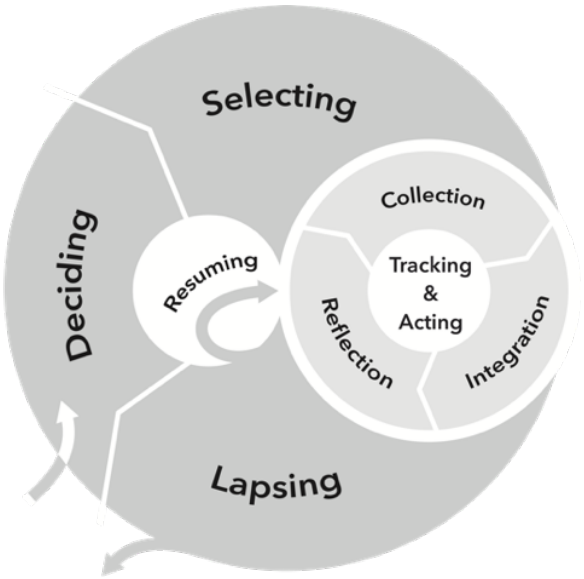


Figure 1. Epstein et al.'s depiction of their Lived informatics model of PI (p. 735)[1]

Where Epstein et al.'s model differs from Li et al.'s, is that it emphasises how users can sometimes stop tracking and how they can enter into any of the processes and abandon them at any point in time, based on their changing personal needs and motivations. In this sense, it visualises Rooksby et al.'s notion that self-tracking can be intermittent Also, where Li et al.'s model had positioned *reflection* and *action* – the key meaning-making processes by which users build knowledge and then act on it – as the end-points of the process, Epstein et al. imply that such meaning-making processes can emerge at any point in the process. Users can engage with the meaning of their experiences and reflect on them when they manually collect data about them or integrate data about them. However, while Epstein et al.'s model captures some of the key ideas presented by Rooksby et al., it still fits self-tracking into a rational, procedural

[1] Re-printed under creative commons license - https://github.com/depstein/lived-informatics accessed 05/01/21

structure, where one event follows on from another, and so it perhaps doesn't fully capture the unpredictability and situatedness of self-tracking as framed by Rooksby et al.

These papers have contributed to the development of a PI field with broader scope. Researchers have started to ask philosophical questions about the purpose of PI technologies and the role that personal data should play in our lives. Elsden et al. (2016) have critiqued the narrow focus on activity tracking and behaviour change in the PI narrative, stating that *"there is much to human experience that cannot be reductively or scientifically understood through simple quantification*,"(p. 48) and suggesting that HCI researchers should focus on *lived experience:*

> "*should question what aspects of lived experience PI can really address, and the implications of a data-driven life for how we experience the world*." (p. 48).

In a similar vein, Rapp and Tirassa (2017) have criticised the narrow focus on behaviour change in PI research, highlighting how this diminishes their scope for providing knowledge about the *self*

> *"The self that these instruments quantify thus is reduced to the data pattern referred to the single behavior/parameter tracked, and the self-knowledge that they actually provide is mere information about how the user behaved in the past." (*p. 337)

On this basis they call for a broadening of focus in PI, with less emphasis on the quantification of behaviours from the past and more emphasis on engagement with subjective experiences from the past, present and future. They envision a paradigm shift in PI, from the study of the quantification of behaviours and activities to engagement with the qualities of subjective

experience more generally. These sentiments chime with observations drawn by Van-Dijk et al. in a review of existing personal informatics literature (Kersten-van Dijk et al. 2017). They note, that although there is clear and consistent evidence that using PI devices can lead to new insights and knowledge, it doesn't necessarily lead to action. They therefore also question the emphasis on behaviour-change as an end goal, and therefore the relevance of the models provided by Li et al. and Epstein et al.

2.3 Designing for meaningful engagement with experiences during everyday life

Researchers are now beginning to explore how PI technologies might be designed so they support broader, and potentially more meaningful engagement with experiences during everyday life. Here, in this section of the literature review, the focus will be on three particular developments: (i) the emergence of *flexible PI technologies (2.3.1)* and *minimalist interaction design for (ii) logging* and *(iii) revisiting data (*2.3.2).

2.3.1 Flexible PI platforms

In recent years, within the HCI and medical technology research fields, there has been increasing interest in *flexible* PI technology platforms. These are systems, which give users more control over their data than typical devices allow by letting them decide what data they will log and how. Ideas relating to flexibility seem to have first emerged in research focusing on PI use in specific medical contexts. It is worth exploring these discussions first, before then discussing literature relating to flexible PI technologies for more general self-tracking in everyday life.

In one of the first papers discussing flexibility in tracking tools, in which they interview 12 people with chronic illnesses, Macleod et al. (MacLeod, Tang, and Carpendale 2013) recognised the value that flexible self-monitoring tools could bring to chronic illness management. Their key observation is that the use of personal informatics tools for healthcare isn't static. They

note that users tend to abandon certain tools because their needs and perspectives change over time, and as such they require tools which can adapt to their ever-evolving set of circumstances. They argue that while it is important that a self-tracking tool provides a structure for chronic illness management, it shouldn't overly restrict the user. As a starting point, self-tracking tools should provide users with a set of templates that they should focus on while logging data. But then over time, as the user learns more about the illness, they should provide suggestions for modifications that they could make.

Building on this, Storni (Storni 2014) explored some of the specific issues surrounding the inflexibility of existing self-monitoring tools. He noted that, perhaps influenced by the clinical focus of healthcare professionals, people suffering from diabetes are often recommended to log numerical biometric data by their doctor (e.g. insulin level, glucose level, food intake) but not the data about their personal experience of the disease. Storni criticised this approach and called for a reframing of the relationship between the clinician, the technology, the disease and the individual who is suffering it. He argues that rather than diabetes being seen as a disease to be treated by the clinician, it should be seen as a lifestyle issue, which can be managed together by the clinician and individual, informed by flexible self-monitoring technologies. It follows that users should be given the capacity to log and self-monitor what it's like for them to experience diabetes in their everyday life, so they can discuss this with the clinician more openly.

In this light, Storni developed the *Tag-it-Yourself* application, with which users can log and monitor how their diabetes condition affects their life more broadly than typical self-monitoring tools allow. Based on a small user study with this app, they draw the conclusion that the greater flexibility of *Tag-it-Yourself* empowers diabetes sufferers, who in the study logged a wide range of elements linked to their condition; from details about the foods they ate, to the feeling of individual symptoms, 'sick days' and daily activities like driving and travelling. Participants interviewed in the study felt that using this information they could have a more constructive dialogue with their doctor about how to manage the disease in their everyday life.

As discussed in the introduction to the thesis, personal informatics technologies have found value in healthcare contexts. This has been noted by Nunes et al. (Nunes et al. 2015) who, based on a literature review of research focusing on technologies for self-care, have observed that HCI can help to open the medical field up to new ways for patients to proactively manage their own health. They suggest that HCI is in a unique position to explore subjective everyday experience in the use of self-care technologies - "*turning the focus away from an objectified view of health to a more holistic view centred on everyday life, they are likely to have a great impact on the lives of patients."* (p1:38). Furthermore, they picture the exploration of flexible self-care technologies in HCI as being essential to addressing the personal differences that people have in their experience and day-to-day- management of an illness.

Since these early studies touched on the use of flexible self-monitoring technologies in the medical field, flexible approaches to PI use have emerged in HCI, which focus on self-tracking for health and for other goals besides. One such flexible device, is Kim et al.'s *Omnitrack* app (2017), which was designed to address the problem that, "*commercial tracking apps are often highly specialized, providing little or no flexibility over what and how to track*." (p. 67:20) *Omnitrack* gives users greater control by letting them setup multiple different 'trackers' within the single app, so they can track multiple aspects of their life simultaneously. Users of *Omnitrack* set a topic , and are thus in control *what* they will log, and then also select *how* they are going to track this topic by setting up data fields for manual or automated logging.

Kim et al. carried out a user study with "*people who have self-tracking experience*" and who are "*interested in self-tracking*" (p. 17). They monitored the usage data of these participants and carried out semi-structured interviews. One notable observation from the study is that participants often chose to use manual data collection methods even when they had the option to use automated ones. Second, although Kim et al. characterise the topics that participants chose generally as '*behaviours'*, many of the ones they reference in their paper have an emphasis on emotion and different aspects of everyday-life experience. Indeed, the most

common style of *tracker* that participants setup in the study is what Kim et al. termed an *In-situ Experience tracker*: when users "*captured an event with surrounding contexts in diverse situations, including mood, exercise, and visited places.*" (p. 19).

This implies that, when given the flexibility to customise and control a self-tracking device, users tend to seek ways to engage with elements of their subjective experience. Further evidence for this comes from a paper by Ayobi et al (2018), in which they examine the practice of *paper bullet journaling* – a paper-based journaling format for rapid logging of bullets, short sentences, numbers and other visual data forms in a pre-determined structure. Despite it not being a digital interface, the authors characterise this kind of analogue life-recording tool as a self-tracking medium because it involves logging and visualising data about life, and because users tend to post images of their bullet journals online on social media platforms.

There are some similarities between this approach to self-tracking and the approach taken with *Omnitrack,* described above. Similar to users of *Omnitrack*, bullet journalists decide on what they are going to track and on how they are going to record data, setting up the data-logging structure of their journal around these decisions. However, it's arguable that bullet journaling gives users greater flexibility and freedom to express themselves than the former. While *Omnitrack* limits users to recording information through 9 different manual logging data fields (*short text, long text, number, ratings, time point, time span, choice, location, image, and audio record*) whose format is prescribed by the system, a bullet-journaling structure can take any practical visual form the user can imagine, as long as it fits within the confines of the paper on which they are working. They can use colours and visual imagery creatively to setup a multi-dimensional logging structure.

Ayobi et al. collected and organised a set of images and related comments about bullet journals from Instagram websites and then analysed this data for themes and clusters. Having done so they evaluated the themes, noting the vast range of different topics and styles of tracker as

well as the creativity of bullet journaling as a self-tracking practice– "*the creative, sketchy, illustrative, and artistic use of pencil and paper,"* (p 28). Furthermore, they noted that the flexibility of the tool allowed users to gradually evolve their self-tracking practice as they progressively created, added-to and switched between bullet journals, responding to the evolution of their goals, skill and time-available. They also noted the capacity of users to express and explore their felt experiences through bullet journals as a way, "*to keep track of and cope with felt experiences in everyday life" (*p. 28). They draw a contrast between bullet journaling and the quantified-self approach, implying that the former supports self-expression and self-exploration to a greater degree.

Drawing inspiration from what they discovered about bullet journaling, Ayobi et al. then developed an app, *Trackly*, for self-tracking with Multiple Sclerosis (Ayobi, Marshall, and Cox 2020). Unlike previous self-tracking apps for multiple sclerosis, which had relied on text and numerical data entry, their bullet journal-inspired approach provides the means for users to log data using pictorial trackers. Users are given the freedom to choose what aspect of life they will track, which image template they would like to use for tracking it (6 options – dinosaur, mandala etc.) and what their colour scheme will be for filling this image in with pictorial data.

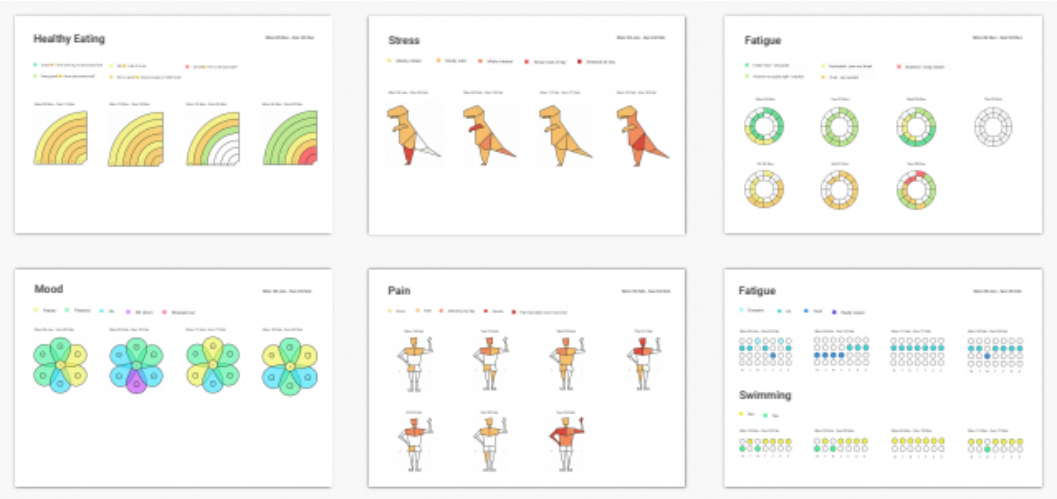


Figure 2 Images from the Trackly app - taken from (Ayobi, Marshall, and Cox 2020) [2]

[2] Image used with permission from the author, Amid Ayobi

Ayobi et al. carried out a four-week user study with their app and then interviewed their participants. They drew a number of insights from the interviews, pointing to some of the attributes of their bullet-journal-inspired self-tracking app approach. Firstly, mirroring their observations about bullet journaling discussed above, they note that the freedom to customise pictorial trackers enhanced the participants' awareness of their everyday experiences. In addition, they note that it seems to have empowered participants, giving them a sense of agency in managing their Multiple Sclerosis condition. Underlining this, Ayobi et al. draw a contrast between their approach, where users self-track general aspects of life that feel meaningful to them as an individual, and the more typical approach to Multiple Sclerosis self-care, where users would track primary disease indicators. They highlight how their approach provides an alternative form of self-care by supporting users' subjective needs and providing a creative outlet for them to engage with personally meaningful experiences.

Thudt et al. (2018) have explored a similar flexible self-tracking approach to Ayobi et al., also giving users the freedom to freely choose what to track and how to track it. However, whereas Ayobi et al. focus on data on the creation of data on a GUI or piece of paper, they explore physicalised data in 3 dimensions. They created a toolkit with which users could setup physicalised trackers, using crafts objects, such as beads, strings, pins and plasticine (see example in Figure 3).

Figure 3. Tracker for recording enjoyment of places visited created by a participant in (Thudt et al. 2018) (p. 148) [3]

Similar to Ayobi et al., Thudt et al. suggest that participants in their user study expressed themselves more openly than they might with a conventional self-tracking app, because they could customise their data: "*Selecting and customizing tokens allowed expressing qualitative experiences that cannot be easily quantified or categorized*" (p. 154). The expressivity of the self-tracking medium is reflected by the range of aspects of life that participants chose to track in the study: *workouts, hip pain, mood, nutrition and bowel movements, distractions during writing, enjoyment of activities, meditation, places visited in a new city, recipes for homemade care products*. It is also evidenced in the way that participants chose to represent their experiences. One participant, for instance, chose to use a large physical map as their self-tracking platform. At the end of each day this participant would stick sewing pins in the map to mark out places they had visited and slot beads onto the pins to register their level-of-enjoyment of that place (see

Figure 3,). Afterwards the participant reported that preceding their participation in the study, they had already been logging places-visited by adding digital pins to Google maps. But comparing the two, they said that they preferred the physical map because it let them add

Alternative, unpublished image from the study included with permission from Dr Alice Thudt

their degree of enjoyment to the record. Like with the previous examples, it appears that the flexibility of this self-tracking platform supported engagement with the emotional, subjective aspects of experience.

The flexible tracking interfaces from Kim et al. (2017), Ayobi et al. (2018) and Thudt et al. (2018) all give users plenty of freedom at the setup stage to personalise their PI tool, when they initially choose what they are going to self-track and how they are going to track it. However, there are greater limits on the users' freedom after this at the actual logging stage. When users start logging data, they have created a logging structure by pre-defining how their experiences will be represented by the data. This lends their tracking practice the consistency for them to measure how their activities and experiences are changing over time. Despite this, in some of the studies there was evidence that users want to be able to evolve and adapt their self-tracking practice. For instance in the bullet journals study, users updated their journal over time, by adding elements, updating them or creating sketches to enhance their content. However, once the fundamental structure of the bullet journal had been created, the general trajectory for it has been set. So while users can steer it and adapt elements of it bit-by-bit over time, they can't completely change its direction. This would require the creation of a completely new tracking structure.

A paper by Lee and Hong (2017), however, points to another approach, which provides a greater degree of flexibility, when users are tracking. They provided users with a broad topic and a completely fluid structure, letting them freely self-define the meaning of each individual piece of data *in-the-moment* when they create the data entry. Their *Mindtracker* platform is an emotion tracking toolkit, with which users create clay models representing their emotions and record them in a partner-app by taking a photograph.

The authors reported that in a user study with this system, participants created unique, self-defined pieces of data each time they logged an emotion. The meanings that users associated

with their models were diverse; ranging from the sensation of "*deliciousness*," to the feeling that "*time is passing*", "*satisfaction*", and being "*disorientated*". Reflecting what Thudt et al. suggested about their self-tracking toolkit, the freeform creativity facilitated by the clay medium seems to have been a key factor in facilitating this expressivity. Users were able to create a range of abstract symbolic forms and associate diverse meanings with them because the system leant them the freedom to do so.

Colour as a flexible data form

The section above has highlighted some of the different forms of data that can be used as a medium for flexible self-tracking. This work suggests that open-ended forms of data, whether clay-models, pictorial trackers, sketched imagery or craft objects, help to support users to express themselves more freely than using the numerical data of typical self-tracking tools.

Given the wide range of potential data forms, this thesis focuses on one specific form of *flexible* data: colour. This section examines how it has been used in HCI research as a medium for self-reporting emotional experiences or communicating them to others; demonstrating why colour data was a suitable focus for the work described in this thesis.

In HCI literature, colour has commonly been used as a form of information through which emotions can be conveyed. This tendency to link colours with emotions is understandable given that there are well-established cultural interpretations of colours as emotional symbolism (Elliot and Maier 2012). In this thesis, this kind of literature, which aims to categorise specific cultural or biologically founded colour associations, is defined as out of scope. The aim here, rather, is to consider colour associations on a case-by-case basis. So, this next section, and all the subsequent sections for the thesis which touch on the use of colour will describe individual cases where colour has been used as an expressive medium, without seeking to relate this to

established colour-meaning systems. In doing so, the intention is to retain an openness to the different ways that colour might be used as a form of expressive data.

HCI literature has demonstrated a number of different ways that users can express or communicate emotion through colour with the help of an interactive device. The different approaches can be differentiated by the degree of control that they give the individual user over the expression and interpretation of their emotions through the colour data. The most restrictive systems give users very limited control. The colour-emotion meaning system is prescribed to the user – i.e. the colours they can log have pre-defined meanings, shown to them by the interface. Other devices give users the freedom to set their own meanings and interpret colour more subjectively.

Prescribed colour-emotion logging: Some researchers have sought to impose a structure on how users can express their emotions through colour. One common approach, which has been frequently used in HCI projects, has been to associate a two-dimensional colour gradient with Russell's circumplex of emotions (Posner, Russell, and Peterson 2005). In an early example, Fagerberg et al. (Fagerberg, Ståhl, and Höök 2004) demonstrated how the colour/circumplex combination might work as a scaffold for users to add a new layer of expressive communication to SMS text messages. They built a prototype app, *EMoto*, with which users could add colour to the background of text messages that they send to others. Users select their colours from a gradient which has been mapped onto Russell's circumplex, with duller and lower temperature colour hues, such as blues and greens, associated with emotions of lower arousal and valence, and higher temperature and brighter colour hues with greater levels of arousal and valence.

Fagerberg et al. don't report on a user study with *EMoto*. However, more recently, their approach has been taken-up and applied in field research. For example, Morris et al. 2010 developed an app for fostering emotional awareness to support mental health employing the same colour/circumplex gradient. Similarly, Rivera-Pelayo et al. 2017 applied it in an app for mood self-tracking in the workplace. Morris et al. and Rivera-Pelayo et al. both report that

using their systems had a positive impact on users. Morris et al. report that using their app seems to have enhanced emotional awareness. They state that participants in their study would look at the data they had logged about their mood, reflect on it and become more aware of how they felt. Rivera Pelayo et al., meanwhile, report that employees reflected on their experiences at work and became more aware of their emotions when logging data.

While these studies provide an indication that logging data using the colour gradient/Russell's circumplex model can support emotional awareness, it is challenging to glean the precise role that colour itself plays. Given that the meaning of the colour gradient Is pre-defined, it is difficult to differentiate whether it was the act of expressing emotion through the medium of colour that helped to enhance the emotional awareness of users or the act of expressing emotion by associating it with the prescribed values of Russell's circumplex – valence and arousal.

Unprescribed colour-emotion logging: It is easier to identify the affect of colour as a medium of emotional expression when users are given the freedom to create their own encodings. One case in point is a study performed by Balaam et al. with the *Subtle Stone*, an affective device (Balaam et al. 2010)(Gallacher et al. 2015). The Subtle Stone is a small translucent ball with an LED and radio transmitter inside, which lights up when squeezed. Each time the ball is squeezed it changes to one of 7 colours. Balaam et al. implemented a set of their Subtle Stone devices in a school-classroom-based user study. Their intention was to explore how pupils might use these devices to convey their emotions to their teacher during lessons. To begin with, the pupils each came up with a colour-meaning system, associating each of the 7 colours with an emotion. Then, during the class, they switched on and selected colours on their Subtle Stones to convey what they were feeling, as and when they saw fit to do so. The teacher received live data, via the radio transmitter inside each ball, to show them which colour each pupil was displaying, on their computer.

Following an interview with the participating pupils and teacher, Balaam et al. report on some of the characteristics of colour as a medium for expressing emotion through a digital device. They note that colour is a very personal to individuals. Users don't necessarily have a collective agreement over which emotion each colour represents, which can cause issues (this resulted in it becoming quite overwhelming for the teacher when trying to interpret the interface on her computer), but on the other hand individuals like the personal, expressive freedom it lends. There is also the added benefit, that the ambiguity of colour allows people to control their privacy. They don't have to share their interpretation of what a given colour means with others, if they don't want to. Balaam et al. also highlight the role that the constraints of the interface play into this. Pupils in their study said that the 7 colours were quite limiting, and didn't account for all their emotions. While this could be a source of frustration for them, it also meant that finding a colour that 'felt right' was a process that seems to have fostered thoughtfulness and potentially reflection.

Similar insights subsequently emerged in a paper by Gallacher, in which they report on colour logging with their *Mood Squeezer* system (Gallacher et al. 2015). The Mood Squeezer system was implemented as a collective data logging system, in the context of the workplace. While walking the corridors of the office; employees could log colours, reflecting their mood, freely at any point during the day, by squeezing a ball. They could also see each of the individual colours they and their colleagues had logged over the course of the day, by looking at the floor panel display. Like Balaam et al., Gallagher et al. note the individual expressivity as being a key characteristic of colour. Similarly, they note that public colour logging onto a shared display can cause frustration in a group setting, when users don't share the same perception of colour-emotion encodings. This again indicates that colour might be better suited to private emotion logging rather than shared logging.

In both the examples just discussed, from Balaam et al. and Gallacher et al., the digital system provides users with the freedom to set a meaning for a colour and express this by creating a digital colour artefact. The range of choices available, however, is limiting in both cases. Balaam

et al.'s Subtle Stone gave users the option to choose from 7 available colours and Gallacher et al.s Mood Squeezer, 6 available colours.

Cheng et al. (2011) have trialled a much more open system of colour selection, providing the means for users to log any colour they like from a colour palette and associate any meaning to it. They designed their app, *GoSlow* with the intention that it might encourage users to slow down and reflect amidst the fast pace of everyday life. The app sends users notifications each evening asking them to record a reflection ("How was your day?"). They can write the reflection in text, select a colour and take a picture with a camera.

Based on a small scale 3-day user study, Cheng et al. report two important insights about the way that colour can be used for self-reporting experiences. First, their study reinforces the idea that colour is a natural medium for expressing emotional aspects of experience. Users in their study used the colour-logging feature of the device to make colour-emotion associations, despite having the freedom to use it in other ways. Second, Cheng et al. hint at some of the expressive nuance that colour can bring to emotion-associations. For example, participants in their study selected a midnight blue when tired and light blue when feeling good.

It seems that by giving users the license to choose a full range of colours Cheng et al. tapped into the expressive range of colour to a greater extent than the previous papers discussed above. Their findings hint at the richness when colour data is seen as a subjective expressive medium. When the users is freed up to log and colour data in a way that makes sense to them as an individual, rather than being constrained by a preset meaning structure. This is also something that Boehner have touched on in their paper, *How Emotion is Made and Measured* (Boehner et al. 2007). They note how the ambiguity of colours can help people to make sense of emotions, which themselves are very personal and often ambiguous. In making this point they reference a number of different interface designs, including *Miro*, an ambient display which conveys the aggregate emotional state of office-workers through swirling abstract colours and shapes. The underlying concept is that users might learn more about their emotions by subjectively interpreting ambiguous representations of their emotions like these

than from a more systematic prescribed breakdown of emotion in terms of cognitivist measurements.

The literature discussed above has demonstrated various ways that users can express their emotions through colour. Several different insights can be summarised about these approaches: Firstly, it is important to note the key general insight that colour can be an effective medium for expressing emotion through an interactive device. The act of associating colours with emotions and interpreting their meanings can evidently have a positive effect on emotional awareness. Secondly, it can be noted that the constraints that the device imposes on colour choice and association can affect the way that users engage with their emotions. Systems which pre-define the meaning of the colours for users, or ask them to pre-define a limited set of colours themselves provide for more structured, but less open expression than those which let users select any colour and associate any meaning with it. The former seem to be adapted to contexts where it is important for users to be able to interpret and measure how their emotions have changed over time, or to be able to communicate their emotions to others. The latter seem to fit contexts where the aim is to foster self-understanding

2.3.2 Minimalist logging with PI technologies

Researchers have noted the tendency of users to abandon self-tracking technologies when they grow frustrated with the workload of logging, managing and reviewing data from day-to-day (Lazar et al. 2015; Harrison et al. 2015). A key issue with flexible self-tracking platforms, is that they potentially exacerbate this problem. Such platforms demand even more decisions about what to log and how to log it than more typical PI devices. Thudt et al. and Ayobi et al both highlight the extra effort involved when users self-track with flexible self-tracking platforms. While Lee and Hong don't comment on the amount of effort required by their *Mindtracker* toolkit (Lee and Hong 2017), it seems reasonable to suggests that creating clay models is not always practical in everyday life and requires an investment of time.

Part of the issue here, is that the majority of these flexible self-tracking tools aren't digitalised. The expressivity of the device seems to be leant by the physicality of the materials, the craft materials, paper and clay that users employ to create the data they log. But these same physical materials also might add to the burden of self-tracking during everyday life. Users must organise and carry the analogue materials with them if they are going to log data. Plus, as highlighted by Thudt et al., analogue materials cannot be reused or adapted in the way that the pixels of a digital device can be.

Users don't always find non-digital materials to be a hindrance. Ayobi et al. observed that bullet journalists often accept the extra effort of using a flexible self-tacking system because they perceive that the rewards of doing so, outweigh the burden. They therefore tend to take their bullet journals with them during everyday life, filling them out on-the-go. However, some users, especially novice users who haven't developed the habit of using flexible self-tracking platforms may be dissuaded by the inconvenience of analogue materials. Bullet journaling, for example, may be daunting for outsiders who aren't immersed in the online culture and haven't developed the habits of *bullet journaling*. This highlights the importance of exploring ways to make manual logging as simple, effortless and approachable as possible without compromising the flexibility and expressivity of the logging itself.

There have been a number of studies which have explored alternative, minimalist PI system designs, emphasising simplicity and ease-of-use. These provide an indication of how systems might be designed which provide a balance of simplicity and expressivity. *SnAPP* (Ferrario et al. 2017) is a system that uses a physical button attached to the audio jack of the user's phone (Figure 4, below). Users manually enter data into the SnAPP app by pressing this button. The advantage of this system design is that a button is tangible and easy to press even when the user is not focusing on the screen of the phone. A field study, in which participants were asked to log their moods over a number of days with the app, showed that users found it easy to log their mood in a range of different situations. *SleepTight* (Choe et al. 2015) is another minimalist PI application. In this case data logging is made simpler because it can be inputted through a

widget on the menu display of the phone. Rather than having to go through the menu and open the app each time they want to enter data into the system, users can enter it simply by tapping on the widget on their home screen. Choe et al. compared this widget-based system, with a more traditional system where the logging interface is hidden within an app and noted that the former design increased adherence levels. Users logged sleep diary data more often with the widget-based app.

Figure 4. Logging data with SnApp by pressing the audio jack button (Ferrario et al. 2017) *(Pages not numbered).*[4]

Although these minimalist interface designs support quick data entry due to the simplicity of the input mechanism - which seems to encourage users to log more often - they also only facilitate low resolution data logging, which compromises their flexibility. Users of *SnAPP* can only record two different types of input, a single button-press for inputting a good mood and a double press for inputting a bad mood. Users of *SleepTight*, meanwhile, have just 5 inputs directly available to them.

An alternative approach, explored by Chong et al. (2015) is a system in which users log a time stamp with a simple, single-input when an experience happens and enter richer data afterwards. They tested a system which allowed users to log the time stamp by squeezing a

[4] Used with permission from Dr Maria Ferrario

bluetooth-connected ball in their pocket. The idea was that later in the day, when they had time to write a diary entry, users could review the time stamps they had logged on their phone and add more contextual details. The disadvantage of this kind of system however, as Chong et al. acknowledged in their paper, is that given the simplicity of the time-stamp entry, users would often forget what the time stamp prompt represented or forget the details of the memory before they had a chance to write the more detailed diary entry.

Colour is a data type that may lend itself to minimalist logging. As discussed in section 2.3.1 above, users seem to be able to express nuances of emotional experiences in a single colour. This implies that there is depth and richness in a single pieces of colour data. It isn't necessary to log several pieces of information to capture that richness. The section above, also pointed to some of the different ways that users can interact to log colour data – tapping or swiping on a GUI display, squeezing a coloured ball, squeezing a ball several times to select a colour. Another way to log colour data, which has been demonstrated by Ryokai et al., and which may provide a particularly minimalist way to log, is to capture the colours from the environment (Ryokai, Marti, and Ishii 2004). They developed IO Brush, a smart paint brush, with which users can capture colours from physical objects and then *paint* them on a smart display. They implemented it in a user study with children and noted that it provided a fun form of tangible interaction, through which the children could explore their environment in a creative way and engage with meaningful objects around them. Ryokai's work provides an example of how colour data can be captured in a fun, engaging and intuitive manner.

2.3.3 Minimalist data displays

An interface where numerous pieces of personal data are presented back to users is a fundamental feature of any PI device. Displaying personal data to users, so they can reflect is a key role of such technologies, which supports the development of self-knowledge. An important question for designers and researchers, therefore, is how data should be displayed

to users and how this might affect the way users engage with and develop self-knowledge from their data.

Early PI literature, driven by the "*self-knowledge through numbers"* mantra, emphasised the importance of displaying data at-scale and integrating it. In a paper where she characterised the self-tracking culture, Lupton highlighted the perceived importance of working with statistics: "*The statistical aspect of the practice of self-tracking – the ability to produce quantifiable information measuring aspects of one's life – is integral to the approach*" (2014) [p. 81]. Other influential works by Whooley et al. (2014) and Li et al.(2012), meanwhile, emphasised the importance of collecting multiple different streams of data and integrating them together, with the former describing the different ways that *quantified selfers* combine data streams to gain insights into their lives and the latter showing how additional streams of contextual data can supplement primary data to enhance insights.

One of the drawbacks of collecting and integrating data at large scale, is that the data can be difficult for users to handle and understand. Researchers have sought ways to address this, by using sensors and algorithms to determine which data integrations users should be shown in a given situation (Hsieh et al. 2013) and developing new forms of visualisation that reduce the visual complexity of displays (Epstein et al. 2014). These approaches sought to adapt the *self-knowledge by numbers* approach, by packaging the data in a more appealing way for users. As the scope of PI research has broadened and the Lived Informatics paradigm has come into focus, however, discourse has highlighted the potential of alternative, minimalist approaches to data visualisation, which seek to reduce the scale of data collection and integration altogether.

In their paper on *documentary informatics* – a category of PI technology-use where the users focus is on documenting life events rather than achieving a specific goal, Elsden et al. have questioned whether it is always necessary for there to be such a focus on scale when displaying data (Elsden et al. 2017). They suggest that when there is a sentimental attachment to the

event, such as a wedding day, there should be less focus on scale because the meaning can get lost within it: "*Masses of data could be constructed as 'true', but evoke almost nothing of the experience, hence meaning little in this context*". They therefore call for smaller scale displays – *snapshot data* (p. 657), and suggest that data displays should be "*poetic*" such that they, "*succinctly distil some essence of the experience*" (p.g 656).

Meanwhile, Rapp and Tirassa (Rapp and Tirassa 2017) have suggested that the approach to displaying data should fit with the needs of users. They have shown that inexperienced users tend to find large scale data visualisations, in which multiple streams of data are integrated together, particularly complex and abstract, which dissuades them from using PI technologies. On this basis, they have called for simpler displays, which provide lower barriers to entry for inexperienced users. They suggest that data should be presented in such a way that users can recognise something of themselves in it and that they should be able to revisit individual memories symbolised within it. This implies an approach where there is less focus on enabling users to engage with data as a mass – through trends, quantification and statistics, and more focus on engaging with individual data pieces and their individual meanings.

In an article in which they project the future direction of PI research Cosley et al. (2017) have highlighted the potential value of "*Displays for direct experience of data"*, in which each individual data piece is presented back to users as it is, rather than organised and aggregated by the system for users. They suggest that these kinds of displays might support "*recollection and reflection*"(p. 200), pointing to one particular paper by Cordeiro et al. (2015), which demonstrates this. When trialling a diet-tracking app, Cordeiro et al.'s observed that users gained the most valuable insights into their dietary habits when revisiting photos of their meals presented in a gallery-style display. There was a richness to each self-contained photo-data piece, which sparked insights that users wouldn't necessarily have had if they were looking at more conventional data e.g. showing how many calories they had consumed in the past week.

As well as being an interesting avenue for future research, providing an alternative way of engaging with experiences, displays through which data can be directly experienced may be starting to emerge because they are necessitated by the move toward alternative data types. Flexible, expressive data types like the photo-data (Cordeiro et al. 2015) and the clay-model-data employed by Lee and Hong (Lee and Hong 2017) don't lend themselves to being aggregated like numerical data. Aggregating data requires that individual data pieces share properties. However, the value of these kinds of data types comes from their individuality rather than their sameness. They are better suited to being displayed directly so they can be re-visited as individual data pieces. As such this is a point at which the emerging research on flexible and minimalist PI technology design coalesces. Alternative, flexible data types which encourage expression lend themselves to more simple visualisations.

So far, in this section, we have focused on *how* data is displayed. One final, important point relating to minimalist data displays, is the question of *where* the data is displayed. The typical approach with PI apps is to position the data display within the interface of an app, such that the user must navigate from the home-screen of their phone, open the app and then select an option to bring up the display. This is also the approach taken with some of the *flexible* PI devices discussed above. However, in the case of non-digital platforms - Thudt et al.'s data physicalisation and Ayobi et al.'s Bullet journaling platforms - the data display remains in a fixed position wherever the user physically left it.

An alternative and more minimalist approach, however - demonstrated by Choe et al. (Choe et al. 2015) - is to situate the data display on a widget on the home screen of the user's phone, such that users can see their data whenever they switch their phone on. By comparing two different designs, one implementing this widget-based approach, and another the more conventional app-based approach, the authors have shown that users seem to have revisited their data more frequently when the display was widget-based. Making the data display more directly accessible, therefore seems to support engagement with data. Another approach is to consider other forms of display entirely, besides a GUI display. Data can be can be embedded in

the environment, for instance. These kinds of alternative, unexplored approaches can provide new opportunities for engage with personal data (Willett, Jansen, and Dragicevic 2017).

2.4 Summary

This chapter has discussed how the focus of PI research has broadened over time, resulting in the development of an increasingly diverse range of ways that users can engage with and learn about themselves through the use of PI technologies. Responding to calls from Rooksby et al. (2014) – who drew attention to the need for greater focus on the needs, whims and motivations of users, and Rapp and Tirassa (2017) – who highlighted the limitations of devices that define life in terms of behaviours and activities, a number of scholars have demonstrated how flexible PI technologies can be designed. These can be considered less as behaviour quantification tools , which is how early PI devices might be described, and more as lenses onto 'felt' subjective experience.

However, to design PI technologies that support meaningful engagement with experiences during everyday life, there are still a number of issues that we face, which have been discussed in the literature review above. These issues relate to three different characteristics of design and user interaction, which themselves are interrelated – *flexibility, minimalist logging and minimalist data display.*

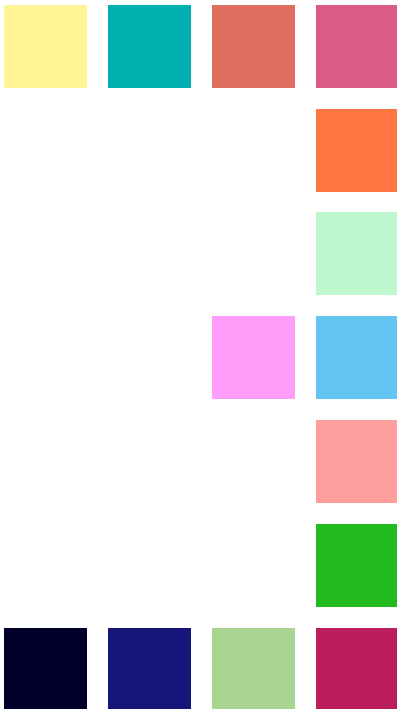
- As part of the shift to a focus on lived informatics, flexibility is emerging as a key focus in PI research. There are a number of different ways in which users can be given *flexibility* to control what they log and how they log it: the flexibility to dynamically choose which aspect of their life they want to gain self-knowledge about, the flexibility to choose how they are going to track this aspect of their life through data, and the flexibility to freely express in-the-moment what feels meaningful to them through the

data they manually log, without this being constrained or diluted by the constraints of the device. In general, systems that allow such flexibilities seem to help people connect with what is personally meaningful in their experiences. However, there are currently few PI devices that demonstrate this. Furthermore, flexible-self-tracking devices for engagement with general experiences during every day life tend to be non-digital devices.

- One of the key issues with PI technologies, is that they can be burdensome to use during everyday life. This issue is accentuated in the case of flexible PI devices, which require users to log their experiences manually, often through effortful, expressive actions. There is evidence to suggest that PI technologies that support *minimalist data logging* interactions may help to address this problem. However, current examples of minimalist PI devices put restrictive constraints on the extent to which users can express themselves when they log data. Therefore it is not yet clear how design characteristics that support flexibility can be married effectively with ones that support minimalist logging.

- As we explore new data types and new ways of engaging with data, it becomes increasingly important to accept new possibilities for how we can visualise data. *Minimalist data displays* through which small quantities of data can be directly-experienced by users, may support meaningful engagement with experiences during everyday life. Research suggests that they make it simple for users to interpret their data, supporting the needs of inexperienced users, and that they can foster meaningful insights about life. However, given the predominant focus on large scale aggregated data displays, there has been little work in this area and there isn't yet a clear understanding of how users might engage with the meaning of their experiences when they use minimalist displays. Nor is there an understanding of the threshold for how minimal the data that is presented can be, before it loses its value altogether.

Having identified these key issues relating to the three interaction design characteristics, an experiential logging tool was developed, taking particular positions on each issue, to probe how users might make use of such a device. This device was designed through an iterative design process and then implemented in an exploratory user study, a process which is described in the next chapter. The approach taken was intended to probe the research space in an open way; helping to refine its framing.



3. SpriteCatcher: An Explorative Technology Probe

This chapter details an explorative study that was carried out with a prototype device. In a 3 day field trial, 9 participants were given the device and open-ended instructions for how they could use it. They were then interviewed at the end of the third day, to probe their user experiences.

The process of planning and conducting this research study has fulfilled two key purposes which serve the broader project. First, deciding what to focus on for the study, a process which involved discussions with external collaborators and iterative prototyping, helped to define the overall aims for the project. In particular, this brought the importance of flexibility and minimalism (covered in the previous literature review chapter), to light. Second, having established these aims for the project, the findings from this exploratory study represent some first steps towards addressing them.

In reporting on this exploratory study, this chapter begins by outlining the iterative design process undertaken, which involved working with external stakeholders to refine the design space, before developing a device that embodies important identified design characteristics. This charts the evolution of the research framing from an original focus on technologies for mental health to the ultimate focus on experiential logging. The later sections of the chapter then detail an open-ended technological probe using the device, to develop an understanding of how flexible and minimalist design characteristics, as embodied in the device, affect how users engage with their experience in their everyday life.

3.1 Research Framing and Design Process

The original motivation for this research was to explore how technologies for mental health might be designed that support vulnerable people in society. This focus was inherited from a smart cities research project that preceded the doctoral research and eventually merged into it. We will begin by describing some of the steps that lay the groundwork for the doctoral research during the smart cities project as a means to provide context for how the doctoral research ultimately came to be framed.

The initial aim of the smart city project was to explore how wellbeing technologies might be designed that support vulnerable people in society. A first step taken toward the objective was to contact local community groups who provide services for the vulnerable, to inform ourselves about the research context. Five meetings were held with individuals who run three groups: a group that supports the homeless (1 meeting), a group that supports people who self-harm (3 meetings) and a group that carry out art projects with disadvantaged and disabled people (1 meeting). These meetings were an opportunity to find out more about the kinds of services these groups provide and the challenges they face, and to explore potential opportunities for collaboration. Notes were taken, and a number of key observations were drawn from these initial discussions that influenced the future direction of the doctoral research.

Important features of the discussion – everyday life, self-expression: One of the common features of the discussions was that they highlighted the importance of engaging with everyday experiences. This was particularly the case with the self-harm support group, that built their entire sessions around engagement with everyday experiences. Service users would arrive, sit together and talk about their experiences and the emotional effects of those experiences. This process helped the service providers to understand the problems faced by their service users, as well as providing a way for the service users to make sense of their own experiences. Providing the service users with a safe space where they could share painful memories with

others who might be experiencing something similar was perceived as a way for them to deal with shame associated with those memories.

Another common feature of the discussions was the emphasis on self-expression as a source of positivity or therapy. Besides the importance of sense-making through aural expression in open discussion, all three groups also pointed to the importance of artistic expression. The arts projects group said that art was an outlet for the disabled to express themselves. They built art projects around this idea. Similar sentiments were discussed by the homelessness and self-harm support groups, who both said they provided pens and paper at each session. The former said that creating art was a positive exercise for the homeless, which could give them a sense of wellbeing. The latter said that doodling while talking helped service users to talk about painful memories more openly because they could divert their attention away from the other eyes in the room. They also explained that art was the only outlet for some regular service users; who would sit in silence for the entire session; just sitting and drawing. They suggested that these were service users who felt unable to speak about painful experiences but still gained something from the artistic expression of their drawings.

Amongst the discussions, the issues mentioned by the self-harm support group, about the mental health and emotional wellbeing of the service users, appeared to be of particular interest, resonating with our own interests as researchers. Therefore, this group was contacted to ask if they would like to meet for a further, more-focused discussion about technologies for mental health and wellbeing.

Design idea: mood diary: In preparation for the meeting that had been organised with the self-harm support group, a number of design ideas were informally sketched out, inspired by the observations described above. One idea was to develop an e-textiles toolkit that the self-harm support group service users could use during the session to create interactive jewellery. It was considered that the service users might use the toolkit to express themselves through their creations in a way similar to how they might express themselves by doodling or drawing in the

sessions. Another idea was to develop a mood diary, with which the participants could record their moods. It was pictured as a tool for making sense of emotions and stimulating discussion in the group sessions. A rudimentary prototype was made to demonstrate what form this might take. Colour was chosen as a data type that users could employ to record their emotions. Colours were interesting because they were seen as a medium through which users might express their emotions intuitively.

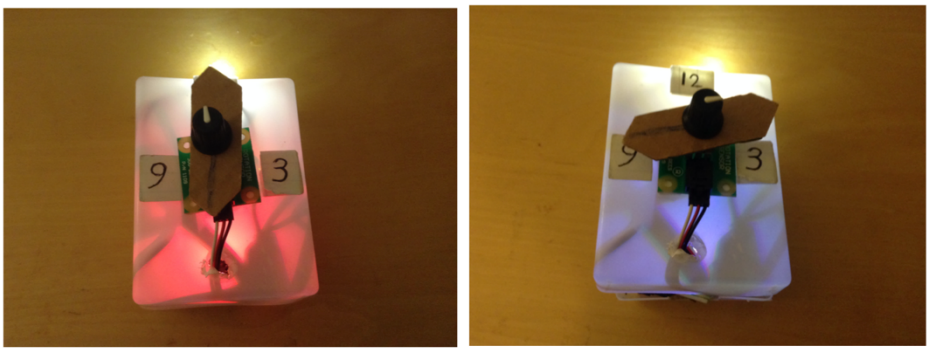


Figure 5: Simple demo prototype of colour-data mood diary

The prototype (Figure 5, above) consisted of a translucent plastic box, with a clock face and rotary encoder fixed to the top. Within the box, there was an RGB LED. The prototype provided a simulation of how colours could be represented as diary entries on a mood diary device. It was envisaged that users would be able to log diary entries at a given time of day and then be able to revisit that diary entry by moving the clock hands back to the time when they logged them.

At this point it wasn't yet clear how users would interact to select colours i.e. create their diary entries. However, this first rudimentary prototype simulated how they might revisit them afterwards. The idea was that if a user had logged a colour at a given time, they could subsequently move the clock hands back to that time to revisit the colour they had logged. Accordingly, the prototype was programmed so that the colour of the LED changed when the

clock hand was moved. When the clock hand was oriented toward 6 pm, a red colour appeared on the LED and when it was oriented toward 9 pm, a blue colour appeared. When the clock-hand was in between these positions, the LED was switched off.

Although it didn't have the full functionality of a device for both logging and revisiting mood diary entries, this low-fidelity prototype was intended to be sufficient to stimulate a discussion with the self-harm group about how it could be used in sessions. In our previous meeting, the trustees had told us about the existing structure of their sessions, where attendees would begin the round-table session by talking about their experience over the previous week. The trustees said they sometimes had difficulty in animating these discussions. The idea with the prototype was that it could demonstrate how a colour mood diary could help with this problem. Attendees could revisit and present 'colours from their week' at the round-table session, and use these as a prompt for discussion.

Three trustees of the self-harm support group were invited to a session in which the design ideas and prototype were presented. Most of the discussion focussed on the prototype mood diary. The trustees said they liked this concept and pointed to several features that they felt could have a positive impact. They liked the decision to use colours as a medium and felt it might provide an effective prompt for attendees at their sessions to express and engage with their emotional experiences. One of the trustees also suggested that colour could be appealing to users because of its ambiguity. Service users would be able to keep their diary entries private because other people wouldn't be able to interpret what the colours represented; their meanings revealed only if the service user chose to decode them. Another of the trustees spoke about how the device could integrate into the existing routines of the service. Service users could log diary entries with the device between sessions and then, if they volunteered to do so, use their diaries to prompt discussion about their memories at the sessions themselves.

We also had a more general discussion about technologies and mental health. One of the service users, who was also a professional counsellor, spoke about tools she used to 'ground'

people in the present when they were feeling mentally unwell. She spoke about how she would use vibrant, physical stimuli, such as candle flames to capture their attention and bring them out of their ruminations. We discussed how digital technologies might replicate this through interaction design that draws attention to the physical world.

Following the meeting, the decision was made to create a fully working prototype of the colour mood diary to be evaluated in a user study. Part of this process included designing how to record colours on a mobile device. Drawing on what the trustee had said about using physical stimuli to 'ground' people in the present, it made sense for users to 'collect' colours from objects in their environment by scanning them with a colour sensor. The device could be designed so it gave the users the sensation of gradually pulling the colour from the environment.

It was at this point, while the device was being prototyped, that the smart city project ended and the decision was taken to carry on working with the self-harm support group as a first step for the doctoral research

The resulting prototype (Figure 6, below) is a tangible interactive mood diary, with which users can log and revisit colours representing their emotions. It features an LED display, clock face and day-of-the-week counter on the front panels (gears inside change the day of the week in accordance with the rotation of the clock hand, a rotary encoder inside records the position of the clock hands). There is a colour sensor on the back, and a swivel-to-open design. An Arduino is inside. The images in the figure were taken when a larger Arduino was temporarily attached to the back for testing.

When they want to record a mood diary entry with the device, the user first turns the clock face to the current time and day of the week so that they can register the diary entry at the appropriate time. They then search the environment for an object with a colour that represents

their mood. Once they have made a decision about which colour to capture and which object to capture it from, they take the device and hold it up to the object. They then press down on the clock face to capture the colour of that object. When the user does so, the colour sensor detects the colour and the LEDs gradually light up to mimic the feeling of pulling the colour from the object. Once captured, the colour is displayed on the LED display.

If the user then moves the clock hands, the colour disappears. However, the colour and the time set with the clock hands and day counter are stored in the memory of the device. This means that the user can revisit the diary entry in the future by moving the clock hands back to the time when they initially made it. When they do so, the colour reappears on the LED display.

Figure 6. Higher fidelity mood diary prototype

The following vignette demonstrates how this might work in a real-life scenario:

Laura suffers from depression. She receives counselling for her illness and attends peer group classes. One day the counsellor gives her the colour mood-diary device and instructs her in how to use it. Laura tucks it away in her handbag. The following day (Saturday) while she is at home, Laura begins to feel anxious. She finds that she is ruminating about something that she heard one of her colleagues at work say. She cannot seem to stop the cycle of negative thoughts tumbling over and over in her head and a feeling of hopelessness and self-dislike is starting to build. She remembers that she was given the sprite catcher device the previous day. She doubts it can help her but decides to dig it out of her handbag anyway.

Laura opens the mood diary by sliding the display around and away from the clock face and then changes the time on the clock to reflect that on her watch. Next, she looks around the room to find something that might reflect her current emotions. She sees an old, forgotten, purple shoe in the corner of the room under a pile of clothes and decides to make that her target. Laura walks over to the shoe, holds the sprite catcher up to it and then presses the button in the centre of the clock face. Suddenly, purple light begins to rush into the display and whizz around, like sprites dancing. She finds that the longer she holds the button down, the more the light rushes in. The feeling of sucking sprites from the shoe into the catcher is unusual but pleasant and it's starting to take Laura's attention away from her ruminations. She lets go of the button when she feels that she has enough of the sprites. Laura finds her ruminations beginning to recede further as she focuses on the calming light display. She closes the device and pops it back into her bag.

At various moments over the next few days, Laura does the same thing – capturing sprites in the device to reflect her experiences. As she does so she starts to notice more of the objects and items that are around her at home, on the bus, at work etc. She becomes curious about what kind of sprites they may produce. This sense of wonder about the world is positive and productive for Laura, it helps her to reactivate the dormant, creative part of her mind and stop focusing on her internal worries. At the end of the week it's time for another group counselling session. During the session, Laura takes the device out of her bag

and begins to use it as a stimulus to talk to the other attendees about her moods over the course of the week. She uses the clock hand to cycle back in time to the beginning of the week and then slowly scrolls back through to the present. As she cycles forwards, the sprites she has captured appear on the display. She talks about each one. She likes how she can direct their attention of the others towards the mood diary rather than towards herself, which makes her feel more comfortable when discussing her experiences. She also likes how the mood diary helps her to remember things she had forgotten. Discussing these experiences with the group helps her to understand them better and make sense of her mood.

The trustees of the self-harm support group were invited to a session to discuss the prototype that had been developed. At the meeting they told us that they liked the idea that it was a standalone device, separate from the user's phone. They also liked the concept of capturing the colours from the environment with it, but commented that the device might be too big, difficult to carry around and potentially fiddly and frustrating to use. These issues were deemed problematic for implementation in a sensitive mental health context, where it is important to avoid frustrating interaction design features that might be detrimental to the users' wellbeing. The self-help group also informed us that unfortunately they had to close down their group due to funding problems. This meant that we wouldn't be able to carry out any research in collaboration with the group.

Technologies for mental health is a highly sensitive HCI research context, where collaboration with professionals who understand the people with whom they are working is crucial. To carry out user research in this context would mean working with vulnerable people and exposing them to experimental prototypes. It was important to consider whether a very open and explorative research approach like this was appropriate and what the risks might be. The designs we were proposing were in very initial stages of research, and we felt that we could not in all confidence say that there weren't risks for the users. That the self-harm support group had to pull out from the collaboration caused us to take a moment's pause to consider the future direction for the project.

Through these discussions we had observed similarities between the themes discussed in the PI literature and the discussions we had been having about technology design with the community groups. In the PI literature, the act of recording aspects of life and then revisiting them is considered to be something that can be positive for users, helping them to make sense of their activities during everyday life. This mirrors how these activities had been pictured in our discussions with the community support groups. However, we also noted that PI technologies tend to be inflexible and only support engagement with experiences in a narrow way, as discussed in the previous chapter, and that there isn't yet a thorough understanding of how to design technologies that support meaningful engagement with a broad set of experiences during everyday life.

Some of the characteristics of the prototype- *colour* as a data type and *capturing* from objects as the mode of logging the data – were considered as interesting approaches to PI technology design that might provide a new angle on these issues. The decision was thus taken to switch focus sightly and concentrate on how PI technologies might be designed so they support meaningful engagement with experiences during everyday life rather than focus on wellbeing. This new focus meant that we could build on what we had learned about technologies for mental health and the prototyping work that had been carried out thus far, but target the general public; a user group who, unlike the service users of the self-harm support group, weren't receiving professional support for acute mental health issues, but who - like anyone in society - could potentially benefit from tools that might help them to engage with the meaning of their experiences.

The broad aim of the research therefore switched from a focus on mental health to the following:

> *To explore how PI technologies might be designed so they support meaningful engagement with experiences during everyday life.*

3.1.1 Changes to initial prototype: simplifying interaction and display and supporting direct data experience

The prototype described above was adapted to fit with the new framing of the research space. The three interaction design characteristics, which were identified as key criteria in the literature review in the previous chapter- *flexibility*, *minimalist logging and minimalist data displays*, became a focus when making these design decisions.

Design characteristics retained

Two of the interaction design characteristics of the device – colour as the data type and capturing from objects as the data logging method, were retained, because, as noted above, they seemed to fit with the goal of making the device flexible enough to support self-expression, while also making it easy to use during everyday life. Building on the discussions with the self-harm support group, we speculated that colour as a medium of expression, might help to make the device more flexible, by enabling users to openly express and engage with the aspects of life that matter to them. In particular, it might provide a medium for people to express emotional aspects of their life.

Capturing colours by scanning objects, meanwhile, was considered to be a quick and easy way for users to select colours because it wouldn't necessitate them scrolling through an interface to make the selection. The user could just look around them, find a colour they liked in their environment and then log it. There was also still something compelling about what the community support group had said about 'grounding' participants by drawing their attention to vibrant physical stimuli. We were interested to explore any affect that this form of interaction might have on experiential engagement.

Design characteristics changed

Several changes were also made to fit with the shift in research framing. One of the themes described in the previous chapter is that PI devices are often burdensome to use during everyday life. Removing the clock face, changing the input to a single button and reducing the scale of the data so that rather than storing all the data that the user had ever logged the display showed only the last four colours they have logged, were seen as ways to hone the design for minimal, simple interactions that fit with everyday life. The mechanism for revisiting data was also changed so that rather than accessing each data-piece individually by moving the clock hand, the last four colours logged would be shown simultaneously on a single display that was always present on the front of the device.

The decision to opt for 4 LEDs on the device and to situate them in a linear time-series structure was motivated by several different factors. We were interested in exploring whether users would revisit and reflect on data on a minimalist device, when they had only a small number of data pieces available to view. If there were too few LEDs users might not be able to recognise patterns in their data and reflect on it. Meanwhile, if there were too many LEDs the pocketable device might feel crowded, compromising the minimalist design principle. 4 LEDs seemed to be a good number, that balanced out these factors.

The plastic-swivel design of the original prototype was also dropped in favour of a smooth, wooden design that might more easily fit in the pocket. The choice of wood, an organic material that is not often associated with digital technology, was intended to make the device more natural-looking and discrete; less like a typical piece of technology and more of a reflection of the environment in which it is being used. These decisions were intended to make the device pleasurable to use, a general UX attribute, while also supporting the specific aim of making it easy and convenient to use during everyday life.

Lastly, it should be noted that, given the focus on minimalist, simple design, it was decided that there should be no notification or reminders system. Notification systems have been heralded as an important way to retain user engagement (Bentley and Tollmar 2013). However, they do so intrusively, grabbing the user's attention and directing it toward their phone with sounds or vibration (Pielot 2017). This doesn't seem to fit with the minimalist interaction approach. Furthermore, while notifications can be programmed to encourage users to interact in specific moments, they don't foster self-motivated interactions in the moments that matter to the individual (Stawarz, Cox, and Blandford 2015).

Together, the design decisions described above resulted in the development of *SpriteCatcher*, a *flexible minimalist experiential logging device*.

3.1.2 Design implementation: SpriteCatcher

SpriteCatcher has a simple, carved pine wood form, a single button to interact with, four LEDs on the front and a colour sensor on the back (Figure 7, below). It is small, sits in the hand and can fit easily into a coat pocket or handbag. It is designed so that users can log their experiences by capturing the colours of objects from their surroundings. When a user presses the button and holds it up to an object, the colour sensor on the back detects the colour and displays it on the topmost LED on the display. When they have chosen a colour they want to record, the user presses the button again to save it to the LED display. This serves the "capturing colours from the environment' interaction we described above.

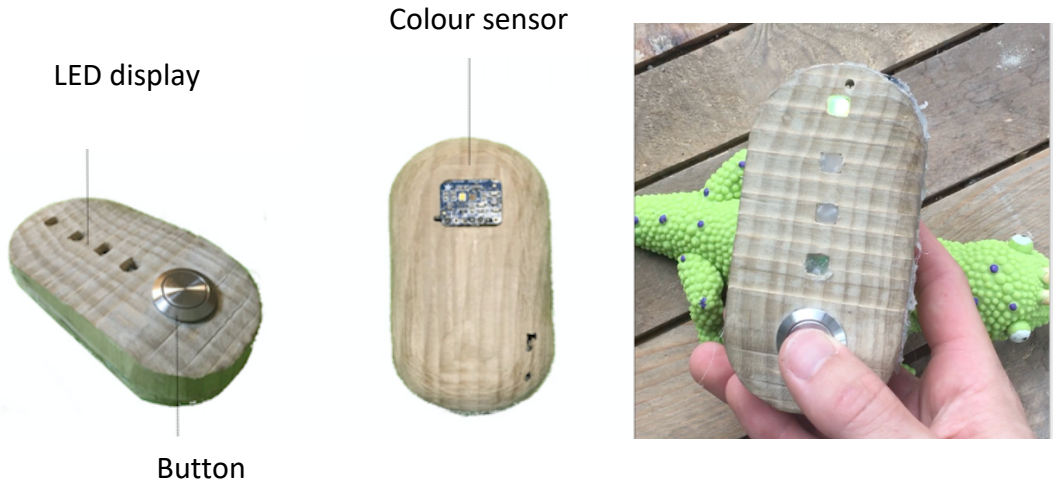


Figure 7. The SpriteCatcher device, here being used to capture the green colour of a toy lizard

The device has a small amount of memory to store timestamps for when colours were captured, but only the last four colours are displayed through the LEDs. Each time a new colour is added, any colours already shown on the display are moved down one place so they are displayed one position below their previous position on the LED strip. Once a fifth colour is captured, the colour on the LED at the bottom is deleted (a first-one-in last-one-out process). The device can be put to sleep (all functionality switched off) and awoken (functionality switched on) by holding down the button. It puts itself to sleep if unused for 2 minutes. The user can delete the most recently stored colour by double clicking the button.

Inside the body of the device, an Arduino microcontroller does all the processing and a Lithium-polymer battery provides the power. The colour sensor is a TCS3472 (300 – 1100 nm wavelength range). The LEDs are WS2812, (465 – 630 nm wavelength range). This range difference means that the LEDs are unable to display colours at the darkest and lightest ends of the spectrum, tending to appear as a white or reddish colour at these wavelengths.

In terms of key design decisions, the *SpriteCatcher* device, as a minimalist experiential logging device, contrasts with typical quantified-self inspired PI device. This is summarised in Table 1, below, which compares *SpriteCatcher* with typical mobile apps and links design decisions for *SpriteCatcher* to themes from the emerging research on flexibility and minimalist interaction design discussed in the previous chapter.

Design property	Typical self-tracking mobile apps	SpriteCatcher	Design Motivation/ Literature links from ch. 2
Data type	Numerical, text	Colour	Flexibility (Page 22)
Device form/ materials	Phone app	Wooden, tangible device	Minimalist logging (Page 35)
Data display	Shows all the data that users have logged	Only last 4 data entries shown.	Minimalist display (Page 38)
Data input	Automated	Manual input through capturing colours from objects	Minimalist logging Flexibility
Topic setting feature	Fixed	No topic	Flexibility (Page 22)

Table 1. Contextualisation of SpriteCatcher design decisions

3.2 Research approach

To support the overall aim of the research described above, the study explores an alternative approach to PI technology design; building on emerging research about flexibility, minimalism and direct experience of data. More specifically, the objective in this first research study was to get initial insight into the research space i.e. how users might meaningfully engage with their experiences during their everyday life when they use an experiential logging technology.
To fulfil this purpose, we could have interviewed or surveyed participants directly; asking them about their use of PI. Or we could have let users interact with a prototype in a lab-setting and asked them about their perspectives on-site. However, the participants' attitudes are likely to have been shaped by their preconceptions about PI technologies in the first case, and it is challenging to simulate the experience of technology-use in everyday life in a lab-setting. Conducting a small scale, 3-day research probe study was deemed the more desirable approach because it would let participants develop perspectives in real-time while using a prototype during everyday life. This seemed the best way to explore the research area and allow space for fresh thinking.

The technology probe approach taken is inspired by the method described by Hutchinson et al. (2003). Building on Gaver et al.'s work on cultural probes (2004), they have demonstrated that giving people a flexible, open-ended digital device to try out for a few days and appropriate in their everyday lives can be a good way to explore a research space; illuminating interesting research questions and future design possibilities. The device can gather data about social dynamics surrounding its use and can prompt discussion between users and researchers, sources of information that can serve as a good reference point for novel research(Hutchinson et al. 2003).

One of the attributes of a technological probe that make it a suitable approach is that it situates the research directly in its context of use, *in-the-wild,* rather than in a lab setting. Rogers (2011), a key advocate of doing HCI research *in-the-wild*, has suggested that when

participants interact with technologies outside of the laboratory, they "*come to understand and appropriate the technologies on their own terms and for their own situated purpose*." (p. 59). This dynamic fits the aims of the research, which is to free users up to explore the device and develop their opinions through open exploration of its characteristics, without being constrained by their preconceptions. It also seems to be a suitable approach because of the kind of context of use we are dealing with. *Everyday life* is difficult to define and tap into. It is challenging for individuals themselves to reflect on what they experience during their everyday life from outside of the everyday. The stance taken in this research project, then, is that only the individual can testify to the kinds of experiences they have, *from within* their everyday life. Discussing scenarios-of-use with participants in a lab-setting can replicate everyday life to a certain extent. However, it doesn't replicate it as effectively as actually taking the device away and trying it out in-context. Dynamics might arise when participants use the device in the everyday context which they might not have expected.

Finally, the technology probe approach is desirable because it places an emphasis on subjective meaning. The aim in this study was to explore how people can engage with the subjective qualities of their experiences in meaningful ways. This necessitates giving users the freedom to define what is significant or meaningful for them rather than prescribing this to them. Giving users an open-ended device, which can be used flexibly and adapted around their own personal needs puts the focus on the individual and how they express what is subjectively meaningful for them through it.

Obtaining data is the biggest challenge with an in-the-wild study. Given that the aim of the present study is to explore how users engage with their subjective experiences, it is important to gather rich qualitative data. Semi-structured interviews, the primary data collection method opted for in the study, provide a way to get such insights. Participants are given some space to direct the interview, letting them express what is meaningful for them as an individual. The drawback of this method, however, is that the participant discusses their experiences after-the-fact, which means the insights are a post-hoc reflection on, rather than direct insight into, their experiences. This issue is mitigated to some degree by the short duration of the study, 3 days,

which means the user should be able to recall details from their experiences fairly effectively. To supplement the interviews and provide a sense of how often users are engaging with the device, some usage data can also be recorded directly from it.

3.2.1 Ethical considerations

A number of ethical issues were considered during the planning of the research study. These issues along with a mitigation plan for how to deal with them were expressed in a formal ethics approval application that was submitted to the university. The plan expressed the duty to protect the privacy of the participants by securely obtaining and storing data and encoding it to keep it anonymous. It also specified that efforts would be made to ensure that participants felt comfortable taking part in the study. They would be informed that they could remove themselves from the study at any point if they felt it might have a negative impact on them. It was also stated that participants would be provided with the details of a professional mental health support group which they could contact if there were concerns about their mental wellbeing. Finally, it was stated that it wasn't necessary to provide financial payment for participation.

3.3 Study design

Participants

A user study was conducted with eight participants who were recruited through personal contacts. The participants were contacted by email and asked if they would like to take part, with a brief summary of what was involved. These participants had a range of different profiles (Table 2, below). In addition, it is important to note that participant P8 said he was partially colour blind, with Deuteranopia, i.e. green-colour blindness.

I.D	Gender	Age	Occupation
1	Female	40	Homemaker
2	Female	28	Full-time MA Student
3	Female	37	Doctor
4	Female	31	Marketing manager
5	Male	35	Engineer
6	Male	32	Full-time PhD Student
7	Male	29	Full-time PhD Student
8	Male	60	Retired

Table 2. Participant profiles for SpriteCatcher study

3.3.1 Procedure

In advance of the study ethical clearance was gained through the university to ensure that ethical practices were followed, as described in the section above. Each participant was invited to a study-setup meeting. In advance of the meeting they were sent a consent form to verify if they would like to take part. It contained a broad summary of the study process and asked consent for data collection and storage.

If participants agreed to the terms of the study, a date was arranged for the meeting. On arrival at the meeting, the consent form was collected, and the participants were introduced to the *SpriteCatcher* device. They were instructed that the device had been designed as a tool for logging colours representing experiences and that using such a tool might support wellbeing. No specific instructions were given on how often to use the device, or at what time of day – this was all left to the participants to decide for themselves. They were told that they were free to explore how they might like to use it themselves. While participants were using the device, it registered usage data for which colours they captured and when they captured them.

The participant took the device away with them for three days. While they had the device, it collected data about which colours they logged with a time stamp representing when they logged them. On the fourth day a second meeting was held, where a semi-structured interview was carried out with the participant. The interview was only very loosely structured. There were no pre-planned questions about specific aspects of technology use. Instead, the questions were left broad and general, e.g., *How did you find it? How did you use it? Can you talk me through the process of using it?* These questions served as a stimulus for unstructured discussion about the nuances of their experiences while using the device. See appendix I (*page 240)*, for the full list of questions that were prepared for the interview.

3.3.2 Analysis

The interviews were video recorded and subsequently transcribed. Usage data from the device was downloaded and was available to the researchers to analyse how participants had used the device. A process of inductive, open-coded thematic analysis was conducted following the 6 stage process described by Braun and Clarke (2006). The approach to thematic analysis mirrored the openness of the approach to interviewing. The grouping of the data was guided by the overall aim of the research study, to explore how users engaged with their experiences

through the use of the device and how this might affect their wellbeing. Other analysis methods, besides thematic analysis could have been used. However, it was felt that thematic analysis fitted the purpose because it provided the openness and flexibility to explore the dataset and identify important themes as they emerged. This method would ensure that we could avoid missing important details and could, rather, adapt the analysis around them. This was important given the exploratory nature of the research.

It is also, recognised, however, that any individual researcher's perspectives can influence the grouping of data. To mitigate any potential extremes in the framing of the data, the lead researcher (i.e., the doctoral candidate) set out the themes initially. The balance and logic of the themes were then verified by other members of the research team (i.e., the doctoral supervisors).

The thematic analysis was conducted according to the five stages enumerated by Braun and Clarke (2006, p. 18-22).

1. *Familiarisation*: For the first stage, the research team sat together to watch the interview footage for two participants, stopping the film to discuss key observations as they emerged. This initial process familiarised the whole research team with the kind of data we would be dealing with. A broad discussion took place to establish first impressions about the dataset and what might be interesting within it.

2. *Coding:* The second stage was carried out initially by the lead researcher, who, drawing on the initial familiarisation discussion with the overall research team, worked individually to code the data, organising it according to interesting low-level features and patterns that were identified.

3. *Searching for themes:* Relationships between the coded data sets were examined by the lead researcher to identify overarching themes. Coded data that didn't fit with any of the themes was at this stage labelled as miscellaneous.

4. *Reviewing themes:* After the themes had been identified, the research team re-convened to discuss them as a valid framing of the data. This was the aforementioned logic-check, rather than a separate independent coding stage. The coded data in the miscellaneous category, was discussed to see if the dataset could be reorganised to accommodate it.

5. D*efining and naming themes:* Adjustments were made to ensure that each data-piece was fitted into the most relevant category and the wording of the categories was adjusted to make sure they were fully representative of the data. The lead researcher then chose overarching higher-level aspects of the themes around which to structure the discussion of the themes (i) the aspects of everyday experience that users were logging (ii) logging and meaning-association (iii) experiential engagement and (iv) usability. This stage was once again verified by the rest of the research team.

All the thematically-organised interview data is presented in appendix II (*page 241*).

3.4 Findings

The interviews and usage data show the participants engaged with their experiences through their use of the *SpriteCatcher* device across the three days; logging colours for a range of different reasons. Table 2, below, provides a breakdown of how many colours each participant recorded on each day of the study. Note that the participants in the study didn't have access to this information. The data was downloaded from the devices when the study had finished. With the exception of participant 6, all the participants recorded at least 2 colours on each day of the study . When asked to explain how the last three days had been in the interviews, the majority of the participants voluntarily described scenarios when they used the device, recounting the experiences they had logged and often which colours they had logged and where they captured them from. The exceptions were participants P6 and P7, who both said that they were unable to find an effective use of the device. This is reflected in the usage data for P6, who stopped using the device after the 1st day. P7 collected colours on all three days but

in relatively low quantities. Both these participants were PhD students. All the other participants were recruited from outside the University setting.

I.D	Day 1	Day 2	Day 3	Total
P1	2	13	13	28
P2	2	23	10	35
P3	12	10	14	36
P4	7	11	16	34
P5	9	8	9	26
P6	22	0	0	22
P7	7	5	9	21
P8	3	6	10	19

Table 3. Number of colours each participant registered per day of the study

3.4.1 Aspects of experience logged

Participants logged a diverse range of experiences with the device. In a general sense, this is reflected by P5's opening statement in his interview:

"*I have the feeling that I did not push the button twice for the same reason.*"

More specifically, the types of experiences they engaged with can be categorised as *sensation-based*, *feeling-based* and *activity-based* experiences. Although in most cases it was clear that one of these aspects of the experience was more dominant, sometimes it was difficult to determine. For example, the following description of an instance-of-use by P1 contains a sensation, feeling and activity: "*I was by the fire and I took yellow, I felt good"* (P1). In such instances, the scenario was considered as fitting into multiple groups.

Logging sensation-based experiences

Four of the participants (P1, P3, P5) described scenarios when they logged *sensation-based* experiences. The first two of these participants (P1 & P3) described occasions when they were capturing aesthetic beauty. For example, P1 said:

> *"I went to the florist and there were a lot of pink flowers. I took several different pink flowers. It wasn't really an emotion, it was a sensation. The colours were beautiful. I liked them. But I can't really explain why I felt the desire to capture them."*

And, P3 said:

> "*I like to take pretty colours. I took lots of clothes... lots of different materials and fabrics."*

P5, meanwhile logged things that they encountered that stood out because of their peculiarity or distinctiveness. One example they gave was:

> "*I pushed the button because a colour was like a firework in my eyes. Yesterday my daughter arrived with very red pyjamas on. I thought, woah it's really red so I took the colour of the pyjamas."*

Logging feeling-based experiences

Five of the participants (P1, P2, P3, P4, P8) described scenarios when they logged colours representing feeling-based experiences. In most cases they logged positive feelings: For example, P8 spoke about using it when he felt "*upbeat"*, P2 said she logged colours when she felt "*good,"* and when she was "*relaxed,*" P4, when she felt "*full of fresh air."* P3, meanwhile said:

> "*I never used it for bad feelings. I don't want to keep bad feelings in the device and keep hold of them."*

There were a few examples of participants logging negative experiences. P8 described occasions when they logged a colour because they felt "*manky,*" and felt "*negative*." P4, meanwhile described examples when they logged the colour of their dining table because they felt a murky, "*wooden table type feeling*," when anticipating the work day ahead. They also logged the grey screen of their computer to represent a "*kind of eeeeh feeling; a too much going on in my brain kind of feeling."*

It is notable that, when recounting the feeling that they had logged, P4 sometimes used unconventional terms. They described the feeling in terms of the objects/colours (*"a wooden table type feeling*") they were logging or a sound ("*eeeh*"). Later in the interview, P4 was asked about how effective they thought colour might be as a way of representing their experiences. They responded that:

> "*It was good for me because I'm not very good with words. It was very visual and that was good for me".*

This perhaps explains why they were describing their feelings in these terms. The objects and colours were an outlet for them to express feelings that were difficult to put into more conventional terms.

Logging activity-based experiences

Three participants (P1, P2, P8) gave examples of logging activities with the device. P1 tended to register the colour of a dominant object in a place that she had been while she was doing an

activity. For example, she registered "*blue, when I went to the sea* and *blue when I went to the swimming pool".*

P2 and P8, meanwhile, tended to log activities according to the time of day or at specific intervals. P2 said;

> "*I tried to use it at different times. I thought it would be important to capture the colour in the morning because I'm not a morning person. And then after I've had my coffee and I'm ready to go out, I scan it again."*

P8 said he used it to bookend the start and end of activities. He said:

> "*...during the course of the day, as situations change, then I used it to capture colours when there was a particular event. Not really an event, but at the completion of one thing and at the start of something else."*

3.4.2 Logging and meaning-association

When they were logging the different kinds of experiences on the device described above, the participants had to capture a colour which they would associate with that experience. They spoke about this process of meaning-association and a number of themes emerged – *significance of context*, *intuitiveness of meaning association* and *logging objects as well as colours.*

Significance of context

Participants appear to have logged colours and associated meanings with them in a fluid, context-dependent way. There was no indication that the participants pre-defined a colour-meaning system so they could log certain colours for certain experiences systematically. They

seem to have been making decisions about which colour to choose *in-the-moment,* and to have made decisions about what a given colour represented on a case-by-case basis. P1, for instance, captured blue to represent the experience of going to the swimming pool, blue for going to the sea and blue again for feeling tired.

Applying meaning to the colours they logged in this fluid way doesn't appear to have been an issue for the participants. Indeed, P4 commented on how she liked the flexibility of colour as a medium for describing what mattered to her in-the-moment. She said:

> "*it fits with where you are, what you're doing, how you're feeling. if you had to label how you're feeling maybe you would call it anger but there are different types of this emotion. Every time you're feeling anger you might not use the same colour. Also, you might not be able to find red*."

P4's last statement, "*you might not be able to find red,*" suggests that the availability of colours had an influence on the decision-making process. Their colour choice was tied to the environmental context in which the experience happened. P8 made a similar remark:

> "*It was all about trying to record stuff that was around you. It isn't a graded sort of thing. All it is recording is how something happened at a particular point in time.*".

Once again emphasising the primacy of context. P8 continued that,

> "*A few days down the line, you've forgotten what a particular colour meant"*

This highlights how the meaning of colours tended to fade over time as they became detached from their original context.

It appears that sometimes the environmental context had more influence still on the logging process. There's evidence that in addition to influencing colour choice, it also sometimes

influenced the decision to log in the first place. P2 described how sometimes a colour would catch her attention and jump out at her. This would then draw her attention to what she was feeling:

> "*If something is interesting or captures my attention, I use it. Not just that. Sometimes because I had a moment to think about how I feel maybe. I think "Ok, I feel like this or that, is there a colour that I can match with that".*

In almost all the scenarios described, participants appear to have been logging colours that were available to them while the experience was happening (e.g., "*I was by the sea and so I captured blue" - P1)*. There was one piece of evidence that sometimes they logged the colour retrospectively after-the-fact. P4 said she logged the experience of walking in the park after she got back:

> "*I used it when I got back from the park. I was feeling revitalized from being out in the fresh air. I captured a green colour from something in the kitchen that conveyed that. Because I felt like I was feeling full of fresh air.*" (P4)

Although this was retrospective logging, it was just after she had got back and could still tap-into the experience. There is a sense that the green colour represented the revitalized feeling from after the walk, just as much as the experience of the walk itself. So even if participants were logging an experience retrospectively, it was an experience that had happened, at most, a few minutes in the past.

Intuitiveness of meaning-association

Some of the participants appear to have found it easy to associate colours with their experiences, deeming them a natural fit, particularly for feelings. As outlined above, P4 said she found colour a more intuitive way to express her feelings than language. P1 expressed a similar sentiment:

> "*It's easier to describe feeling with colours. Colours are spontaneous. I just take the device and I think… this colour... I don't think so much. When you use words, it is different."*

Participants P6, P7 and P8, however, appear to have found associating colours notably more difficult than the others. P6 and P7 completely struggled with the whole task and didn't understand how they could convey experiences through colours at all. P8's issues were less severe. But he seems to have been anxious to know if the colours he chose were adequate for the experiences he was recording. He said that:

> "*I found the selection the most difficult part because I struggled to relate a colour to particular events. So, for instance, when I was in the bathroom, and I was pleased to have lost a bit of weight, it was like. Well, what's positive? Green, let's say. because green was a positive sort of colour."*.

Later in the interview he spoke about:

> "*trying to contrive what would be the most relevant colour. So what I thought at the time, was that the most positive colour would be the green of the towel." I just went for the towels because they looked green, although my wife says they are yellow. but, as you know, I'm colour blind."*

Although he himself was able to determine which colour he felt was most adequate, P8's life-long partial colour blindness may have affected his confidence in his choices. He wanted to know which colour would be socially acceptable.

Logging objects as well as colours

It's notable that some of the participants said they recorded materials despite the device not being capable of capturing patterns. As mentioned above, P4 captured the colour of wood for a

"*wooden table type feeling"* and P8 captured the dark mahogany wood of the mantelpiece to represent their hangover. He also gave the example that, *"I was quite upbeat and so it was the wine bottle. It wasn't the object, the wine bottle, it was the association of the red wine with the day."* P3, meanwhile, captured the colours of the materials of her clothes, to register their aesthetic qualities. This indicates that sometimes participants were drawn to the object from which they were taking a colour, as much as to the colour itself. There is also a sense that the participants were curious about the technology and were exploring its limits.

3.4.3 Experiential engagement

It appears that using the device prompted users to engage with the meaning of their experiences. There is evidence to suggest that the process of logging colours helped to foster reflection on experiences, elevate awareness of experiences and support self-regulation.

It should be noted that there are no examples where participants looked at the colours on the device and then drew meaning from them. Indeed, they don't appear to have used the display as a history of their previous logs at all. The only times they mentioned the display in the interviews was in referring to it as a feedback mechanism; for scanning and testing different colours before saving them (e.g., "*I was disappointed because the colour displayed does not always match with the colour I wanted to capture. It's not exactly the same colour*." (P3)

Reflection

There are 3 statements from the interviews that indicate that sometimes participants were reflecting on their experiences when logging them. Two of the participants, P1 and P2 spoke generally about how using the device helped them to understand their emotions:

> "*I like choosing a colour for my emotions it helps me to understand."* (P1)

P4 said:

> "*It was quite hard because it's not something I normally do, is registering how I'm feeling. Normally, I'm like, I've got stuff to do or I need to be somewhere. So, I think forcing myself to take note of how I was feeling at different times was good." (*P4)

P8, meanwhile, gave a more specific example, where he described how logging the colour had helped him to reflect on his decisions the previous day:

> "*To begin with it was getting up, how do I feel when I get up? Well, on Saturday morning I didn't feel too good because I'd had too much to drink on Friday night. But it did focus my mind on thinking, well, I shouldn't have really done that. It was a case of trying to find a colour that matched that. It was like hardwood. It was a hardwood, mahogany colour."*

Awareness

In the quotes cited in the previous paragraph both P4 and P5 implied that logging experiences with the device sharpened their attention, making them think more carefully about something (*"forcing myself to take note*," P4) (*"it did focus my mind*", P8). Using the device directed their attention to an element of their everyday experiences that they would have overlooked, fostering awareness.

In addition, two participants (P3 and P5) explained that using the device made them more aware of their environment:

> "*When you use this, you are more attentive when you look at the things around yourself"* (P3)

“I am much more focused on the colour of things than normally when I don't have the device. Because I am looking for situations when it is interesting to push the button.” (P5)

For participant 5, the increased attentiveness to the colours he encountered made him feel generally more aware of the little details in his everyday experiences that would otherwise seem mundane and unimportant. He reflected on this and said that:

“*It makes me think that I live more than usually, because I have more memories. In particular, it is the free time that we totally forget.”*

Regulating emotions

Given that participants were often logging present experiences, while they were happening, e.g., “*I did a few during the course of the day. I was putting the shed up and it was a case of being happy to be at the end of it.* (p8), the act of logging them sometimes appears to have influenced the experience. P2 reported that she captured colours in her bathroom after having had a shower:

“*There were nice, calming colours and I just felt really relaxed and I thought, right, I'll capture this as well.”*

This implies that using the device brought her attention to affective, *calming* colours. Another example comes from P1 who said,

“After my visit to the hairdresser I was not happy at all. I was searching for the colour red and I felt better”.

P1 also gave an example where capturing a colour helped her to express how she felt to another person, which then in turn helped her to regulate her emotions. She explained that during dinner her son didn't want to eat something, and she showed it to him and said:

"*Look, I took dark pink*. *Because I am not very happy. He watched me with his big eyes and I felt more calm, I think*."

3.4.4 Usability

In general, the participants appeared to have liked the design and found it simple and fun to use. However, they reported a number of usability issues. Because of these issues, participants only used the device under certain conditions. In particular, they chose to use it in calm situations, when they had free time and mental space.

Participants reported that they needed a free mind to use the device. One reason for this was that they struggled to keep the device close to hand. P2 and P3 both spoke about not being able to fit it in their pocket. P2 also said she struggled to find it quickly when she put it in her bag. P4 and P8, meanwhile, said that it was "*too big,*" to be practical. On-the-other-hand, P5, said that the size of the device was a positive attribute. Feeling the presence of the device in his pocket became a prompt for him to remember to use it.

Another obstacle to using the device was that it demanded visual attention and so participants had to stop an activity to use it. P3 and P4 both indicated that this presented a barrier-to-use in the workplace (e.g., "*When I am at work, I have no time to do this."* [P3]). P5, likewise, said he didn't feel inclined to interrupt the flow of his work to use it; P1, meanwhile, said she liked to use it when she felt '*Zen*'.

Another factor that affected when people chose to use the device appears to have been concerns about privacy. P3, P4 and P5, meanwhile, all mentioned that they felt self-conscious when using the device in public. P3 said she often became anxious, wondering "*Who's looking at me now?"* when she wanted to use it. P4 said:

"*I did use it at work, but it's a bit more awkward, because you're out in the open plan desk area, and people can see what you're doing*."

P5, meanwhile, said:

"*I made it very quick, to avoid people looking at me and saying 'What is it that he's doing with the device? what is it for?' It felt a bit like I am stealing the colour."*

Furthermore, he said that it felt like it was violating his privacy:

"*I make a parallel with Facebook. When I live something, I keep it for me. I don't explain my life on Facebook. This device is inside my privacy. Taking the colour. Even if it is just colour. It goes deep in my privacy."*

Toward the end of the interview, the participants were asked what could be done to improve on the design. P1 and P3 offered an opinion on the LED interface, suggesting that it could have more LEDs, P3 arguing:

"*You could have all the colours from a day. More LEDs. Before sleeping you can see all the colours from the day*"

P8, however suggested that he would only want more LEDs if the idea was to measure experiences, like his moods, more systematically. But it would not be necessary for the way he used it in the trial, which was to, "*record events and things like that*."

"I don't know whether seeing more lights would help. It's about what you're trying to achieve. If the meaning of the colours is already set for you, then you're on a set scale for recording mood. Then you can put yourself on a set scale for mood. But if you're wanting to record events and things like that then it's how do you associate that with a particular colour".

Three of the participants (P5, P3, P1) said that the colour mapping was sometimes inaccurate and could be improved on. P1 noticed that "*it can't capture white*." Finally, three participants (P8, P2, P3) said that they felt that it might be more convenient to use if it were a phone app.

3.5 Discussion

The discussion that follows consists of four sections. The first two of these sections (*Engagement with diverse subjective experiences - 3.5.1, Engagement in-the-moment through logging - 3.5.2)* cover observations about the way that users log data and associate it with their experiences. The third section (*Relationships between design characteristics, logging behaviour and experiential engagement - 3.5.3)* brings elements from the first two sections together to discuss how design characteristics affect the way users log and engage with their experiences. The fourth section (*Minimalism and Convenience)* discusses why convenience is a key priority for users and how minimalist design plays into this.

3.5.1 Engagement with diverse subjective experiences

One of the key observations from the study is that participants engaged with a range of different experiences with the device while logging colours for them. This is notable because it contrasts with the utilitarian, behaviour-focused manner, in which users tend to engage with their experiences with conventional PI technologies. In addition to engaging with their activities – as they might with more conventional self-tracking applications – the participants engaged with emotional and sensory aspects of their experiences. When the study was setup, participants were given the example that they could log emotional experiences, which may have encouraged them to focus on emotional aspects of experience. However, the extent to which they did so in the study reinforces previous work that has shown that users find colour to be an intuitive medium through which to express emotions (Fagerberg, Ståhl, and Höök 2004; Balaam et al. 2010) This kind of interaction seems to tap into the relationships between the

sensory and emotional aspects of experience. Even when users were logging an activity such as *going to the sea* or *sitting by the fire*, there is a sense that they were logging the *felt experience* of that activity. The aesthetics of the sea or the fire, along with the emotional experience of being in that place.

Logging colours was never the kind of systematic, rational act of *data collection* that has been pictured in quantified-self media (Lupton 2014) and in early PI research, e.g., (Li, Dey, and Forlizzi 2010). It is perhaps better considered as a form of *expression*. This reflects how it has been portrayed in the flexible self-tracking literature of Lee and Hong (2017), Thudt et al. (2018) and Ayobi et al.(2018). As such, *SpriteCatcher* can be classed with these other forms of flexible PI technology within the broader family of PI technologies. In the sense that users were constrained to only logging data through one medium – colour, SpriteCatcher is less flexible than these systems. However, on the other hand, given that there is no defined topic or established tracking framework for the meaning of the data they log, it has a greater level of flexibility.

3.5.2 Engagement in-the-moment through logging

The *way* that the participants engaged with their experiences with *SpriteCatcher* was striking. Rather than engaging with their experiences by analysing data they had already logged, as users might with a PI application following Li et al.'s PI model (2010), the participants were engaging *while* they were logging the data. Perhaps surprisingly, they don't appear to have viewed the data display as a source of meaning at all. They didn't use the display to compare their data over time, they viewed it simply as a feedback mechanism for verifying the accuracy of colours they recorded.

Not being able to see historical data doesn't appear to have been a significant issue for participants. This reflects what Rooksby et al. (2014) have said about the way users focus on

the present, or the very near future or past, when using a PI device. It also reflects findings by Mols et al. (2020), who have noted that even when users are confronted with media representing experiences from the past, it becomes a prompt for them to think about something more recent.

There appear to be a number of implications for this kind of experiential engagement. The study reinforced evidence from recent literature suggesting that the act of creating data entries can be a prompt for users to reflect and develop self-knowledge (Ayobi et al. 2018; Thudt et al. 2018; Choe et al. 2014). In particular, the findings resonate with Ayobi et al.'s (2018) observation that PI technologies, which let users express their experiences more freely through the data creation act, can support reflection on subjective experiences. Adding to this, the findings imply that the act of logging data draws the user's attention to the qualities of their experiences; providing a platform for reflective thinking. There is a sense that the externalisation of the experience in data fosters reflection. However, while there are indications that this might be the case, it hasn't been made concrete because the participants spoke generally about how they were affected by their use of the device rather than in specific terms. This makes it difficult to unpack whether or not we have solid evidence that the device fostered reflection.

Out of the five different styles of tracking defined by Rooksby et al.(2014), the way users logged data with the *SpriteCatcher* devices seems to bear the closest resemblance to *documentary tracking,* in that users were logging data simply for the purpose of logging them rather than because they wanted to change a particular type of behaviour. However, there is a difference, in that users were logging data purely because they found the act of logging it meaningful as a self-contained process, rather than because they wanted to document life events to reflect back on afterwards. In this sense, it might better be described as *expression-driven logging*, rather than *documentary tracking*.

3.5.3 Relationships between design properties, logging behaviour and experiential engagement

A key question to consider is why these dynamics emerged, why did users engage with their subjective experiences and focus on engaging with the meaning of these experiences through the act of logging? One of the key factors could be methodological. The study put very few limits on how users could engage with their experiences through the device and so participants naturally sought to appropriate the device to what mattered to them. Second, and perhaps more importantly, however, the design of the device seems to have encouraged them to do so.

One aspect of the design that seems to have had this effect was the data type: colour. The symbolic ambiguity of colour encouraged participants to engage with their experiences openly. This corresponds with the PI research by Lee and Hong (2017), which has shown that when users have to self-define what their data means, they tend to engage with and express the nuances of those experiences through the data.

Although users could freely self-define the meaning of the colours they logged, colour as a symbolic medium doesn't appear to have been a completely *blank canvas*. There was a tendency for participants to express emotional meanings with the colours they logged, indicating an inherent relationship between colour and emotions. This reflects ideas that have been well-established in cognitive psychology research by, amongst others, Elliot and Meier (2012) and Goldstein (2006). Because it possesses this property, colour as a data type, appears to address what Elsden et al.'s have called the need for, "*poetic data creation… that distils some of the essence of the experience*" (Elsden et al. 2017) (p.656). There are clear indications that users can use colour to express meaning. It should be noted that this isn't always the case though and that some people find it easier to express themselves with colour than others.

A second aspect of the interaction design that seems to have encouraged users to engage with their subjective experiences in-the-moment is the way the device made them log those

experiences. Capturing colours from the environment seems to have naturally directed the user's attention outwards toward the place where those experiences were taking place; situating experiential engagement in the physical world. Users had to physically go and touch objects with the device to grab their colour. The sensory stimuli of the environment was therefore a much more integral part of the user experience than in more conventional PI devices. By drawing their attention to sensory stimuli and grounding it in a present context, *capturing colours* became a part of those experiences; affecting how users felt and giving rise to new elements of their experience. This is perhaps another reason why *present* experience was such a focus.

It can be speculated that the capture act may have fostered what phenomenologists term situated cognition or *immersion-in-the-world* (Seamon 2015). This link to phenomenology seems to be most clearly manifested in participant 4's use of embodied metaphors (e.g. "*a wooden table type feeling*"/ "*feeling full of fresh air*") to describe the experiences they logged, as well as in the way that objects could sometimes be as much a focus for users when they were logging as the colours they were capturing from them. Expanding on this philosophical line of thinking, it can be argued that by asking the user to engage with their environment, the device seems to be anchoring the experience of data-logging in the physical world; such that the user isn't just processing the experience cognitively in their brain alone, but as a form of embodied cognition. This relates to how Paul Dourish has pictured embodied interaction with technologies (2004).

There appears to be a physicality to the experiential engagement when users capture colour data from physical objects, which seems to draw their attention out beyond the digital confines of the device they are using. Rather than focusing on aggregated data on the device as they might with a more conventional PI device, users are engaging directly with individual experiences in the world. The device acts as a lens onto the physical world rather than a digital representation of it. One of the key implications of this is that it brings the experience and the act of logging it together. The data logging act becomes part of the experience that is being logged and has influence on that experience. Participants in the study noted how logging

sometimes changed how they felt in-the-moment, elevating or regulating their mood. Or sometimes seeing colours became a prompt for them to look inwards and think about their experiences more deeply than they would otherwise.

A third feature of the device that seems to have had an influence on how users engage with their experiences is the small scale of the display. It seems that this may have been encouraging them to engage with what was happening in-the-moment, because they didn't have the facility to look further back at data from the more distant past. Once again colour, as a data type, seems to have played into this dynamic. The study indicated that there was a transient quality to the colours that users logged, where they lost their meaning soon after they had been logged and could be quickly applied to new meanings. This all seems to add to the short-termism of experiential engagement with the device. There isn't the same continuity to the data that PI devices with longer-term histories support.

Although two of the participants in the study suggested that they might like to see more data displayed on the device, this doesn't seem to have been a major focus for them. It was notable that one of the participants spoke about how he would only need more data if he wanted to measure something. He saw the device as having a different purpose; it was about engaging with the meaning of experiences that were happening in-the-moment rather than measuring them over time. At the time, however, given that the study design meant users didn't get to try out a larger data display, it is difficult to make claims about the comparative value of short and longitudinal data displays.

3.5.4 Minimalism, usability and convenience

The effectiveness of the minimalist design approach can be weighed up in different ways. On the one hand, it was effective in minimising the physical effort required. Unlike in previous minimalist approaches to PI technology design (Ferrario et al. e 2017; Chong et al. 2015; Choe et al. 2015), users were able to record complex meanings about their experiences with a single button press in-the-moment, while the experience was happening; something which they seem to have enjoyed doing. This efficacy can be largely owed to the data type, colour. A single colour, captured with the single button can evidently be applied to a range of different meanings.

It should be acknowledged, however, that while the design allowed simple, expressive logging, it wasn't conducive to this in all situations. There were issues with the interface design, which meant the device was inconvenient to use in certain situations. The physical act of scanning colours made people feel socially conscious and the relatively large size of the device, for some people, made it difficult to store and carry around. Furthermore, the extreme minimalism of the display might have contributed to users having not revisited their previously logged data. If the display had more than four data pieces, users might have engaged with it to a greater degree.

3.6 Limitations

The purpose of this study was to exploratively probe the research space and provide insight into how users might engage with an alternative form of PI device. While this explorative approach provides a stimulus for fresh thinking and a way to shape and refine the framing of the research space, it is limited in terms of its scope and the generalisability of the findings it provides.

Given the small sample size and the short duration of the user study it isn't valid to make broad claims about the way that users engage with such technologies. To an extent, the three days of in-the-wild technology-use simulated how users might use the device during their everyday life. However, given the short length of the study, it is likely that there was a novelty bias when users received the device, which would have affected the way they used it throughout; probably elevating their level of engagement above what it would be in general everyday life. Furthermore, the participant sample is unrepresentative of broader society. The participants were sourced through personal contacts and this is likely to have narrowed their diversity. There are also inherent limitations to the data collection methods. The validity of the themes derived from the interviews is dependent on participants being able to accurately recall the experiences they were describing. This cannot be guaranteed. Participants may have been re-evaluating or re-interpreting what had happened post-hoc, meaning that the findings are not truly representative of the experiences of the participants at the time when they were using the device. Finally, in the setting up of the study, participants were given the example that they could use the device to log how they felt. This may have influenced the way users chose to use the device, encouraging them to engage with feeling-based experiences when they may not have otherwise done so.

Given these limitations, the outcomes from the study should be considered as preliminary findings, which highlight interesting perspectives on the design of PI technologies for experiential logging that can be pursued further in the follow-up research.

3.7 Conclusion

An overall aim for this project - *To explore how PI technologies might be designed so they support meaningful engagement with experiences during everyday life* - has gradually crystallised through the process of framing, planning and conducting the research described in this chapter.

As well as helping us to formulate the overall aim for the research project, the technological probe study carried out with *SpriteCatcher*, has provided some preliminary insights with which to address it. Some general observations can be stated about *flexibility*, *minimalism* and *reflection*, the key concepts that are the central focus in our three research questions (page. 13) and which feed off the overall aim.

- *Flexibility*: *SpriteCatcher* was shown to be a highly flexible PI device, supporting engagement with a broad range of emotion-rich, subjective experiences. The device was designed for manual logging of colour data, through a capture interaction and a small scale display. Together these design features gave the device a dynamism, such that users were willing to connect with their ever-changing feelings, switch their focus between different types of experiences and different colour-meaning associations from moment to moment, when using it.

- Within the broader scheme of PI technologies, SpriteCatcher can be considered as being at the extreme end of flexibility. Where previous flexible PI devices, as discussed in the previous chapter, provide the freedom for users to steer their logging practices in different directions from day-to-day, by changing topic or adding features or fields to the logging structure they have set for themself, SpriteCatcher appears to permits sudden switches in direction from minute to minute. There is no system or consistency to their logging; users engage with whatever feels meaningful in a given moment. The advantage of this greater level of flexibility, is users can react to what matters to them from moment-to-moment, when they use the device with little constraint at all. They aren't constrained by the way they set up the self-tracking platform or by the constraints of the data available to them to choose from. A possible disadvantage is that, given the lack of structure to how meaning is applied to data, the data seems to only be meaningful in the moment when it is logged. It loses its value quickly, such that users don’t reflect on it afterwards.

- *Minimalism*: The wooden, single-button interface and simple, direct display appear to have been effective in making *SpriteCatcher* easy to use. However, the capture logging method and the wooden form of the device, while making it fun and appealing, also made it difficult and inconvenient, especially within the cut and thrust of everyday life. This highlights the importance of not only thinking about minimalist design in terms of the physical positioning of buttons and displays on the interface, but in terms of how users have to use their bodies when they interact. Furthermore, it highlights how users want mobile devices to be discrete so they don't attract attention from others when using them. A genuinely minimalist PI design is therefore one that mitigates social as well as physical burdens of everyday use.

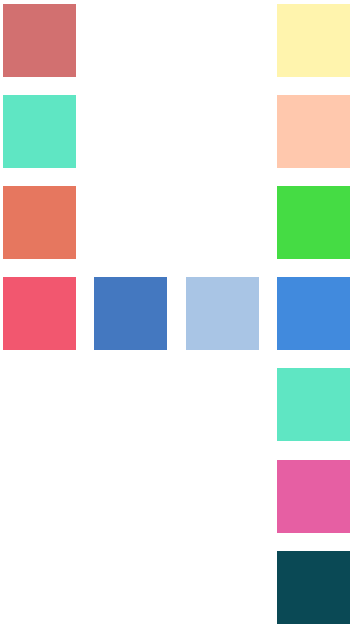
- Reflection: The *SpriteCatcher* data display served as feedback for the user to check which colour they were scanning and validated that they had logged a colour. Therefore it played a role in how users engaged with their experiences when using the device. However, it didn't provide a stimulus for users to reflect on their data and take action (Li, Dey, and Forlizzi 2010). Participants simply didn't engage with the display in this way. It is possible that the data display was too small for it to have meaning, or that users logged their data with such an extreme lack of structure that the displayed data became meaningless for them.

  On the other hand, the act of expressively logging colour data and associating the data with experiences appears to have fostered reflection and other modes of thinking closely related to this – awareness and self-regulation. The process of logging data seems to have encouraged users to take note of the qualities in their experiences during their everyday life.

These last observations about reflection are made particularly tentatively because reflection is a complex process that might be easily misunderstood or misrepresented. At this stage in the

project we hadn't developed sufficient knowledge of how reflection has been interpreted in research literature to be able to concretely determine whether users were reflecting or not and what the implications might be.

Building on this, the next chapter (chapter 4) is a literature review about reflection as a concept. This background on reflection sets a platform for addressing RQ 3 (*How do users reflect when they use experiential logging devices and what does this tell us about how reflection should be conceptualised within PI?)* as a key focus in chapter 5.



4. Reflection with Personal Informatics technologies: A Literature Review

This second literature review focuses on the concept of reflection in the context of PI research. As the conclusion of the previous chapter stated, reflection can be considered as a key dynamic when users are engaging with a PI device. We saw some evidence for this in the *SpriteCatcher* study from the previous chapter. Further examination of the role that reflection plays when users interact with experiential logging devices like *SpriteCatcher* is necessary to better understand how to design technologies which can support meaning engagement with experiences during everyday life.

This chapter reviews literature on reflection in the PI research space, to lay a foundation for further prototyping and user studies. It begins with a discussion of how reflection has been defined outside of HCI (Section 4.1) and then frames how it has been applied thus far within HCI (Section 4.2) and within PI research (Section 4.3). In doing so, this chapter highlights some of the continuities and discontinuities in how reflection has been framed.

4.1 Reflection in literature Outside HCI

In his book *How We Think*, the educational philosopher John Dewey established what is perhaps the most-commonly cited definition of reflection, one which has become the basis for many subsequent definitions of reflection:

> *"Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends."* (Dewey 2006) (p.6)

There are three key parts to this definition: first, Dewey points to some of the qualities of the thought process when an individual reflects. Not only are they thinking *carefull*y, they are doing so *actively* - highlighting the intentionality of the thought process - and *persistently* - highlighting how they think repeatedly on a problem. Dewey claims that these characteristics

are what makes reflective thinking a higher-order form of cognition. While the mind flitters from place to place when individuals think in non-reflective ways, there is a consistency and a deliberate targeting and *connecting-together* of thoughts when they reflect:

> "*...reflective thought is like this random coursing of things through the mind in that it consists of a succession of things thought of but it is unlike, in that the mere chance occurrence of any chance 'something or other' in an irregular sequence does not suffice. Reflection involves not simply a sequence of ideas, but a consequence — a consecutive ordering.*" (p. 2)

Second, Dewey's definition emphasises the level of discipline and effort that is required when people reflect. They have to intentionally reflect and to be willing to think about problems carefully for a period of time, in order to resolve them. Dewey therefore pictures reflection as a challenging process, claiming that people have an "*inertia that inclines one to accept suggestions at face value*," and that to reflect they need to have a *"willingness to endure a condition of mental unrest and disturbance."* (p. 13) Dewey suggests that there needs to be some perplexity, ambiguity or doubt, which focuses the mind on finding a resolution:

> *"...perplexity is the steadying and guiding factor in the entire process of reflection…a question to be answered, an ambiguity to be resolved, sets up an end and holds the current of ideas to a definite channel."* (p. 11)

Third, Dewey's definition provides a sense of what kinds of phenomena people are targeting when they reflect and how they are orienting themselves toward those phenomena – "*any belief or supposed form of knowledge in light of the grounds that support it and the further conclusions to which it tends"*. The outcome of reflection is therefore not only that the individual considers knowledge or beliefs, but that they also build on or develop it in some way. Reflection therefore results in some form of change to knowledge or beliefs.

Dewey's approach to reflection can be considered as a rationalist-technical model, rooted in the principles of his pragmatist philosophy. Through this lens, true knowledge is considered as

being attainable through a logic-driven reflective process. Individuals receive information and actively construct knowledge by experiencing it and acting on it. Until they are faced by perplexity, they don't doubt their knowledge; it is the perplexity that opens up the mind to facts and other evidence that provide the basis for logical analysis and questioning.

The rationalist underpinning of Dewey's model has been critiqued by Hébert for its emphasis on technique, process and rational verification of knowledge, given that it leaves little room for the uncertainty or doubt that people may experience when they change beliefs or perspectives (Hébert 2015). Furthermore, Hébert argues that the reliance on perplexity as a stimulus for reflection provides little space for reflection on the routine, less noticeable moments that make up much of everyday life. This potential limitation of Dewey's approach is important given the focus on '*the everyday*' in this dissertation.

4.1.1 Reflection and action

Dewey's interpretation has been the basis for a lot of the subsequent conceptual work on reflection and has spurred debate about the nature of reflection. One such area of discussion covers the role that physical action plays in the reflective process.

Dewey talks about *reflective action* as a possible end point of a reflective process. Reflection is a meta-cognitive process, which consists of the individual thinking about their own thoughts. Taking action on the reflection is a separate operation that the individual can choose to do afterwards. This implies that the relationship between cognition and action is linear. The reflective work is done internally in the brain, and action is a separate validation step that tests the conclusions that have been drawn afterwards. This position has received support from others, including Gore and Zeichner (1991), and Noffke and Brennan (1988). Notably, these researchers approach reflection from an educational perspective like Dewey. Their perception

of action seems to fit with the structure of the lesson-reflection-lesson structure of this work environment. They see reflection as something that teachers should do when a lesson is finished, to inform the next lesson they teach.

Donald Schön approaches the problem from a different position. In his book on reflection in the workplace, *The Reflective Practitioner* (Schön 1983), he has proposed an alternative interpretation of the relationship between reflection and action. He recognises the form of reflection described by Dewey, where reflection is separate from action. However, he introduces another process in which the two are tied together as part of a single process – reflection-in-action.

For Schön, reflection-in-action is when, rather than reflecting on their actions after-the-fact, individuals reflect directly *through* their actions while they are being enacted. As such, reflection and action are intimately bound up together, feeding off one another:

> "*Doing extends thinking in the tests, moves and probes of experimental action, and reflection feeds on doing and its results. Each feeds the other, and each sets boundaries for the other. It is the surprising result of action that triggers reflection, and it is the production of a satisfactory move that brings reflection temporarily to a close* (p. 280)."

Reflection-in-action is a process where actions have a more direct influence on the reflective process. Action is no longer only a validation end point. It can also be a direct contributor to the cognitive process. Actions and cognition dovetail each other dynamically and repeatedly. Actions unearth gaps in knowledge - informing reflection - which then informs action, and the loop continues. In this sense, reflection can be thought of as a dialogue or, as Schön puts it, a form of *back-talk* with the self.

Schön's approach has a different epistemological underpinning to Dewey's. It puts greater emphasis on experience and intuition as a source of knowledge. Reflection in-action involves a certain amount of *feeling* one's way to a new framing of an event or experience. Individuals aren't sense-making in the same procedural, reason-based fashion that is implied by Dewey's pragmatist framing. The greater emphasis on learning through feel is perhaps best characterised by Schön's description of effective reflective practitioners as having '*artful competence'* (p 19) (Yanow and Tsoukas 2009).

Some scholars have questioned the extent to which reflection-in-action is practically implementable in the way Schön describes it. Gilroy (1993), for example, has criticised the logic of Schön's epistemology; arguing that it implies infinite regress, i.e., the knowledge produced by reflection can only be recognised by further reflection, which in turn requires further reflection to recognise it as knowledge. Nevertheless, the fundamentals of Schön's ideas, that reflection and action can be closely intertwined in a dynamic, active reflective process, in particular when people are in the midst of an activity, have largely been supported (Hickson 2011).

4.1.2 Reflective depth

In addition to being defined in terms of different relationships between reflection and action, reflection can be conceptualised in terms of different levels of depth. There are two levels to this. Firstly, there is discussion about how deeply the individual should consider their knowledge and how this should be differentiated. The sociologist Mezirow introduced the term critical reflection, to define instances when users consider their knowledge more deeply than when reflecting *normally*. Mezirow suggests that the difference between the two is that critical

reflection involves a consideration of the foundations of their beliefs or perspectives, resulting in a deeper, epistemic *transformation*.

> *"…reflection involves the assessment of the assumption implicit in beliefs, including beliefs about how to solve problems…Critical reflection addresses the question of the justification for the very premises on which problems are posed or defined in the first place… becoming critically aware of our own presuppositions involves challenging our established and habitual patterns of expectation, the meaning perspectives with which we have made sense out of our encounters with the world, others, and ourselves.."*
> (Mezirow 1990)

This attempt to differentiate between different types of reflection has provoked debate about where the lines should be drawn. Some have argued that knowledge must be considered in light of particular types of evidence and theory for the reflective thinking to be considered as critical (Fook 2018). Others have argued that distinctions are less clear-cut and that there is no objective difference between reflective and critical-reflective thought at all. Brookfield, for instance, has argued that whether or not reflection is considered to be critical is dependent on the ideology of the individual (Brookfield 2009).

There are also different interpretations of the effect that reflective thought process ought to have on individuals, in particular whether it should involve a shift in perspective. Some have taken an open approach suggesting that there are different forms of reflection and that lighter forms don't necessarily involve a shift in perspectives (Ward and McCotter 2004). Others have a more inflexible interpretation, implying that reflection always involves a shift in perspectives (Kember et al. 1999).

These differences in how reflection has been conceptualised underline the difficulty of operationalising a single, agreed definition. Individual interpretations of reflection seem to be partly shaped by the research context in which they are being conceptualised. For example, it is understandable that the idea of *critical reflection* has gained most traction in educational research because this is a context where the focus is on learning and there is opportunity for learners to draw on the different resources, theory and evidence required to inform their reflections. In the same sense there is little surprise that reflection-in-action has gained traction in workplace contexts, where there is an emphasis on thinking while *acting-out* work-related duties and there is little time to stop and ponder the foundations of perplexing problems.

4.2 Conceptual frameworks of reflection in HCI

Over the last decade, propagated by the transition to third-wave HCI (Bødker 2006), reflection has emerged as an increasingly important concept in HCI research. However, despite being frequently pointed to as a key dynamic in the interaction between the technology and its user, there has been a general lack of clarity in how it has been applied. Baumer et al. (2014) (p. 93) and Slovak et al. (2017) have both recognised that despite the breadth of its usage, reflection as a concept is rarely well-defined and has not been consistently or effectively applied in HCI. Baumer et al. found that among 76 papers resulting from a search in the ACM digital library (using the terms "reflect," "reflecting," or "reflection" as keywords), only 30 provided a definition for reflection. Amongst these, only 20 provided a citation for their definition. They conclude that:

> "...*little work actually explicitly defines what reflection is, and even less grounds the definition in a conceptual or theoretical framework*." (Baumer et al. 2014) (p. 585)

Meanwhile, Slovak et al. (2017) have noted a general oversimplification of reflection in HCI. They comment that although many authors suggest that exposing users to information can support reflection, they generally underestimate how difficult it is to scaffold:

> "*The intricacies of how people do reflect and how the reflection process can be supported through technology seems to be mostly missing from the HCI work so far."* (p. 2696)

Two key pieces of literature which have provided a conceptual framework of reflection for HCI research are discussed in this section. The first appears in Baumer's paper on *reflective informatics* (Baumer 2015), in which they define three conceptual dimensions of reflection. The second is in Fleck and Fitzpatrick's paper (2010) where they set out a framework, describing reflection in HCI in terms of 5 different levels of reflection.

4.2.1 Baumer's Model

Baumer (2015) marks out three broad dimensions of reflection that he suggests researchers and designers can focus on. The first of these – *breakdown* - is what causes users to reflect in the first place. He describes breakdown as being when users detect, "*disturbing anomalies…violating expectations*," (p. 590). He recommends that designers should try to provoke *breakdown* through their interaction design:

> "...*drawing attention to or even inducing breakdowns may provide opportunities for moments of reflection*." (p. 590)

Baumer gives two examples of situations when users might encounter breakdowns. One of these, is that personal data about a user's activities can *violate their expectations* when it doesn't fit with their assumptions. Another is that a system can *violate their expectations* by doing something random such as providing spontaneous delays or slowing down interactions. Baumer appears to put an emphasis on surprising users to disrupt and divert them away from their usual thought patterns.

Baumer's second concept, *inquiry*, is when users *examine* inconsistencies in their knowledge and seek an explanation, through *"iterative hypothesis testing and refinement*", (p. 590)" and the "*re-examination of knowledge and its origins*." (p. 590) This is the fundamental cognitive process first described by Dewey, where an individual is questioning their perceptions or beliefs in the formation of new knowledge. Baumer states that inquiry is best thought of as a form of critical inquiry, an examination of, "*not knowledge itself but the origins thereof, i.e., epistemological inquiry*." (p.591)

Baumer describes a number of different examples to demonstrate this, all of which involve processing or manipulating information. This includes a PI technology example, where after violating expectations, users examine the "*interdependence between dimensions*," of their data. In general, Baumer's perspective on inquiry seems to bear the closest resemblance to how Mezirow has pictured the process of critical reflection (Mezirow 1990). It seems that for Baumer, inquiry means questioning the foundations or "*origins*" of perceptions or beliefs, not just the perceptions or beliefs themselves.

Finally, Baumer frames *transformation* as his third conceptual dimension. This means "*change to the fundamental, basic conceptualization of a situation*," (p. 491) citing Mezirow's concept of critical reflection. Baumer suggests that this may be the most challenging design problem of all:

> "*the greatest challenge to designers because interactive systems tend to "embody a particular stance or conceptualization of a situation*" (p. 591).

The examples that Baumer cites imply that users need to be confronted by information that is presented in an unexpected way to foster transformation. This resonates with how he has described the process of breakdown. The randomness or strangeness in the information that users encounter is key for bringing about a transformation of perspectives. He gives the overall impression that provoking users through the interaction design of the system is important, both to trigger the reflective thought process and then to fulfil it.

4.2.2 Fleck and Fitzpatrick's Model

Fleck and Fitzpatrick (2010) take a different approach to Baumer. Rather than employing broad concepts to frame how reflection emerges through interaction, they provide a level-based framing of different types of reflection, operationalising the characteristics of each level of reflection with detailed descriptions. This approach borrows from one proposed in the educational research of Hatton and Smith (1995), who suggest that there are different forms of reflection, which can be tiered. The levels of Fleck and Fitzpatrick's framework, along with techniques for supporting them with technology, are presented in Table 4 (next page). It should be noted that Fleck and Fitzpatrick themselves do not present their framework in the form of a table, but it is presented here in this form to provide a concise depiction of what they write in prose. The columns of the table are titled with the names (levels and techniques) used in the sections in Fleck and Fitzpatrick's paper along with excerpts taken from each given section.

Similar to Baumer, Fleck and Fitzpatrick frame the presentation, manipulation and re-visitation of information on an interface as being key mechanisms for the emergence of reflection (*"Technology can be used as the tool through which knowledge and experience is recorded"* (p. 218)*/ "produce a record of events which can be looked at again." (*p. 220)) The tiering of Fleck and Fitzpatrick's model is structured by the depth and scope of the evaluation of the information. At the bottom level, *Reflective description* is focusing one dimension of beliefs or perspectives and doesn't involve a shift in perspective, *Dialogic reflection* has a broader scope because the user is exploring relationships between information about different *dimensions* of their beliefs or perspectives, and does involve a shift in perspective. *Transformative reflection* has more depth again, because in addition to exploring relationships, the user is considering their fundamental basis and experiencing a significant shift in perspective*. Critical reflection,* as the top level, additionally requires application of social or ethical issues to the generation of insights.

Levels of Reflection			TECHNIQUES FOR SUPPORTING REFLECTION
0 *(non-reflective)*	*Revisiting*	*"Description or statement about events without further elaboration or explanation. Not reflective."* (p. 217)	*"Technology can be used as the tool through which knowledge and experience is recorded"* (p. 219)
1	*Reflective Description: Revisiting with Explanation*	*"Description including justification or reasons for action or interpretation, but in a reportive or descriptive way. No alternate explanations explored, limited analysis and no change of perspective."* (p. 218)	"*Asking of reflective questions*" (p. 219) - "*The presence of another person is also beneficial in encouraging the giving of justifications or explanations*" (p. 219)
2	*Dialogic Reflection: Exploring Relationships*	*"Looking for relationships between pieces of experience or knowledge, evidence of cycles of interpreting and questioning, consideration of different explanations, hypothesis and other points of view."* (p. 218)	*"Produce a record of events which can be looked at again"* (p. 220) *"A record of collected sensor data can also allow you to look back on experience with the added extra perspective of more information available to understand events'.* (p. 220) *"Technology can also provide the means by which reflectors reorganize their knowledge to see it from multiple perspectives."* (p. 220)

3	*Transformative Reflection: Fundamental Change*	*"Revisiting an event or knowledge with intent to re-organise and/or do something differently. Asking of fundamental questions and challenging personal assumptions leading to a change in practice or understanding."* (p. 218)	"*Levels 3 and 4 build on the processes of levels 0-2 where the resources available for reflection are engaged with at deep levels… Because these levels are much more about what people are doing with the information for change and transformation, i.e., more as internal processes, we will not include any further specific technology examples here. This is not to say that technology will not have a role to play in the actual practice of transformation but that arguably the main role for technology is in supporting the foundational resources and processes of reflection*." (p. 221)
4	*Critical Reflection: Wider Implications*	*"Where social and ethical issues are taken into consideration. Generally considering the (much wider) picture."* (p. 218)	

Table 4. A summary of the 5 levels in Fleck and Fitzpatricks framework of reflection for HCI.

4.2.3 Comparing the two conceptual frameworks

The two frameworks emphasise different aspects of how users might reflect through their use of technologies. Fleck and Fitzpatrick's puts more emphasis on how they reflect by cognitively processing experiences and information about those experiences. Baumer's puts more emphasis on the role of the device and how it can provocatively prompt users to reflect. Of the two, Baumer frames reflection in the more extreme way, picturing it as a more demanding, by-definition-transformational process. It seems to imply that the system should invoke reflection by jolting users into a reflective state through its interaction design. Fleck and Fitzpatrick's

model, by comparison, is more flexible; accommodating lighter moments of reflection, which aren't intentionally provoked by the system. This is probably most distinctive in the case of *descriptive reflection*, where reflection is deemed to arise when users identify and describe the features of an experience. Note their interpretation of descriptive reflection as a form of reflection that doesn't necessarily involve a change in perspectives or beliefs.

Another characteristic difference is that the two models frame critical reflection differently. Baumer implies that critical reflection is a feature of all reflection. However, for Fleck and Fitzpatrick, critical and transformative reflection are only the highest tiers of reflection. The latter's separation of critical and transformative reflection as two separate processes is particularly notable because it doesn't correspond with the research literature they are basing their framework on. In both Mezirow's and Hatton and Smith's work, which Fleck and Fitzpatrick cite as foundations for their model, transformation is deemed to be a product of critical reflection (i.e. critical reflection results in a fundamental transformation of perspectives and beliefs rather than a separate entity). It's possible that they separate them in this way to suit the HCI context, but this isn't made clear in the paper.

Some aspects of the conceptual reflection literature discussed in section 1, which are pertinent for the focus of this research, are missing from both frameworks. One of these is an explanation of how reflection-in-action fits in. As explained in the previous section of the literature review, reflection-in-action is a process where reflection emerges directly through actions. In a HCI context this might be directly through the interactions with a device or from actions *while* using the device. Although Baumer does cite Schön 's work (1983) as one of the foundations for his conceptual framework, he doesn't then go on to explain how it relates to the processes of breakdown, inquiry and transformation. Fleck and Fitzpatrick, meanwhile make no reference to Schön's work at all. All of the examples that they give, frame reflection as emerging from reflection-on-action, i.e., users are reflecting while writing, organising or annotating information about their actions pot-hoc.

4.3 Reflection in PI and related fields

This section of the literature review focusses on how reflection has been framed in the PI field and in overlapping fields, which are closely associated with it - including Lifelogging (Lindley et al. 2011), media supported reflection (Mols, Van Den Hoven, and Eggen 2020) and ambiguous technologies (W. W. Gaver, Beaver, and Benford 2003). Two key aspects of the framing of reflection are emphasised in the review of literature: *how reflection has been defined* and *how reflection emerges from different forms of interaction*. The latter provides an insight into how the design characteristics of the device affect the way that users reflect.

The review is structured in three parts: *PI, lifelogging* and *media supported reflection*. The summary section at the end shows how the themes discussed cut across the boundaries between these research areas.

4.3.1 Reflection in PI

The stated aim of PI technologies is to support behaviour change by helping people to learn about themselves and enhance their self-knowledge (Li, Dey, and Forlizzi 2010). Reflection, as the catalyst for learning, is recognised as being a key contributor to this. As such, there has been substantial discussion in PI research about the dynamics of reflection in PI technology-use and how it can be fostered through interaction design. This next section covers how reflection has been interpreted as a process in PI literature (*reflection as a transformative process*) and when it is perceived to emerge.

Reflection as a transformative process

Reflection seems to have been rarely defined directly in PI literature (Baumer et al. 2014). However, a general picture of how it has been interpreted can be gleaned indirectly from how its effects have been perceived. This is the case, with Li et al.'s seminal paper, which seems to have set a template for interpreting reflection as a *transformative process*.

Li et al. (2010) position reflection as one of the five stages in their stage-based model of PI. They situate it as the 4th stage in their model, nestled between integration and action (with the full model including preparation – collection – integration – reflection – action). Although Li et al. don't provide one specific definition for reflection, their interpretation of what it means can be inferred from the way they describe the *action* process in their model. They state that *action* is when "*people choose what they are going to do with their newfound understanding of themselves*" (pg. 562). This implies that reflection is a transformative process that involves the development of newfound understanding that users can act on.

Others have since taken a similar position on reflection with PI devices emphasising its role as a transformative process that catalyses behavioural change. Cox et al. (2013), for example, have suggested that users can have *digital epiphanies* when interacting with data - moments when they have a striking realisation about something and make a conscious decision to change their behaviour. Thudt et al.(Thudt et al. 2018), meanwhile, have claimed that most instances of the instances of reflection detected in their field trial were transformative because they can be linked to changes in action and beliefs.

This interpretation of reflection as a transformative process seems to resonate with how Mezirow has defined critical reflection (Mezirow 1990) and the way that Baumer has pictured it as "*a change to the fundamental, basic conceptualization of a situation*"(2015) (p.591).

When users reflect

Li et al. suggest that there are two different occasions when users can reflect while using PI technologies: (i) when they revisit data that has been displayed back to them a period after it has been logged, which they call "*long term-reflection*", and (ii) when they look at data just after it has been logged, *short-term reflection*. This separation of reflection with PI technologies into two types – reflection when revisiting data and when logging data - has been a common feature in discourse about reflection in PI literature, also underpinning the way that Epstein et al. model reflection in their *Lived Informatics model* (2015). This next section describes these two types of reflection to provide an insight into how reflection emerges from different forms of interaction:

(i) Reflection when revisiting data:

The processes by which users can reflect when they revisit data is well established in literature. There seems to be general consensus that users can reflect when they observe trends in their data that contribute to their knowledge. Li et al. described reflection on data as being when users '*compare personal information between different times and it reveals trends and patterns."(p. 562).* Others, have described it in similar terms, with Thudt et al. as describing it as the "*identification of patterns, trends, correlations and relationships of attributes within the data*" (Thudt et al. 2018) (p.149) and Cuttone et al. as a process of data analysis (Cuttone, Petersen, and Larsen 2014). This idea that reflection emerges from an analysis of the relationships between data resonates with Fleck and Fitzpatrick's description of *Dialogic reflection* as, "looking for relationships between different pieces of experience."

The *way* that data is displayed on a device may affect the emergence of reflection from when users revisit it on the display. The conventional approach is to visualise data so users can understand it easily, with the system preparing it and presenting it to users so they can grasp its meaning quickly. However, there is an argument that there should be some degree of ambiguity in the presentation of the data to encourage reflective thinking. Kim et al. trialled an app that implemented ambiguous data representations (N. W. Kim et al. 2019) and have recommended that designers focus on "*unconventional encodings to create an element of surprise and stimulate reflection*" (p. 80). This resonates with the discussions in sections 4.1 ad 4.2 above. The sense of perplexity, or as Baumer terms it *moment of breakdown*, when faced with ambiguous data might incite users to reflect, overcoming what Dewey has called the "*inertia that inclines one to accept suggestions at face value*" (p.13).

These ideas about a link between ambiguity and reflection, are also reminiscent of observations made by Gaver et al. in their work on ambiguous technologies (2003). They noted a tendency for users to try and create meaning when they encounter ambiguity. For example, in Gaver et al.'s *History Tablecloth* study (W. Gaver et al. 2006), where users were seen to derive meaning from ambiguous light sequences on a tablecloth even when they were random. In Gaver's words, ambiguity "*encourages people to consider the personal significance of things, behaviours, or events in their environment*" and can, "*draw attention to overlooked aspects of the environment to encourage reflection on their significance"* (2003). It seems that users are inclined to bringing some order to the chaos of ambiguity, and through this structuring process they generate new perspectives.

Mirroring what Baumer's observations about the way reflection is treated conceptually in HCI, most of the papers discussed above defined reflection with a light touch or not at all, failing to provide an explicit referenced definition. However, given that the focus is on self-knowledge and behaviour change in PI literature, they generally seem to carry the same underlying assumption that reflection on data visualisations can bring about significant moments of transformative reflection, provoking users to question their beliefs and change their behaviour.

Choe et al. (2017), who have attempted to frame reflection in a more nuanced way than most, have provided evidence which challenges this assumption. They carried out a study where they asked participants in a lab setting to explore a set of personal data visualisations. This involved a *think-aloud* data collection method, where users discussed their thoughts as they explored the visualisations. Analysing this data and associating it with different levels of Fleck and Fitzpatricks framework, they found multiple instances when users exhibited level 1 (reflective description) and level 2 (dialogic reflection), but few examples of level 3 (transformative reflection), and no examples of level 4 (critical reflection).

Choe et al.'s study was carried out in a lab-setting where users were asked to explore relationships between their data. This is a manufactured situation where participants were encouraged to revisit their data by the methodological design of the study. Therefore, while it can be said that the findings provide some indication that *revisiting data* is more likely to foster lower level, shallower forms of reflection, the context in which the research data was collected, limits the validity of these claims. In an *in-the-wild-setting*, without having been explicitly asked to explore a set of data visualisations, it is questionable whether users would have reflected on their data in the same way or extent.

(ii) Reflection at the time of logging:

There are a number of different ways that users can reflect at the time of logging, which have been discussed in literature. First, users can reflect on new data that has been automatically collected by the device and shown to them in real-time. This is what Li et al. appear to have been referring to with the notion of short term-reflection. Whooley et al. (2014) deconstructed this process further, analysing how the real-time data that users reflect on while engaged in an activity can influence their performance. They cite the example of an exercise bike, where in addition to reflecting on data about a ride as a whole when they have finished their bike ride, users might reflect on more immediate feedback about their ongoing performance while they are riding, using this to measure and optimise their physical effort.

Second, it has been suggested that the act of physically logging data through manual data logging can give rise to reflective thinking. This idea was touched on in Choe et al.'s paper (2014) on the practices of *quantified-selfers*, in which they described how users "feel intimacy with data" and "make sense of it", when they manually collect it. [p1151]. It has since been expanded on in flexible PI literature. Although they don't describe the reflective process in much detail, Ayobi et al. (2018) imply that users reflect in the act of adding new data to their bullet journal as they review and add data simultaneously. Thudt et al. (2018), who provide a more detailed breakdown of the reflective process, have suggested that the physical manipulation of materials to create data contributes to the users understanding of the experiences it represents.

Something that Whooley et al., Ayobi et al. and Thudt et al. share in common, is that they all suggest that the process of reflection they describe can be associated with Schön's concept of reflection-in-action. In the Whooley et al.'s case this association makes sense because the user is reflecting on an experience that is in-motion and this is informing the experience. In the example they give, the user is receiving data and reflecting on it while they are riding the bike, which is then informing how they ride the bike. This can be defined as an instance of reflection-in-action because the user remains engaged in the activity they are reflecting on while they are reflecting. There is a clear resemblance here to what Schön calls "*back-talk*": "*…doing extends thinking in the tests, moves and probes of experimental action, and reflection feeds on doing and its results. Each feeds the other, and each sets boundaries for the other*." (p.280)

However, when users are manually entering data into a system to record an experience after-the-fact, as often seem to have been the case in examples given by Ayobi et al. and Thudt et al., there isn't necessarily this same direct connection and dovetailing of the actions and reflection. The action of entering the data is not a part of what they are recording, it is a step apart; an end-point when the user looks back and reflects post-hoc. For example, when users in Thudt's study (2018) created physicalised data tokens representing the places they had visited and their enjoyment of those places (*Chapter 2, p. 27*) they were creating the data and reflecting on

the experience at the end of the day after they had visited the place. Their summary of how much they enjoyed the place was therefore a post-hoc perspective. This separation between the experience they are reflecting on and the act of logging data about it means there is a disjoint between the two. Reflecting on the experience cannot *feed* into, and *set the boundaries* for, the action of recording it. It therefore seems more valid to describe such examples as instances of reflection-on-action.

This doesn't mean that the process of logging data cannot induce reflection-in-action. It just suggests that the process of logging the data might need to be a part of the activity, rather than separate from it, if it is to do so. Some PI devices are designed so they necessitate this through their design. Parker's diet-tracking app (2014), was designed so that users would have to take pictures of their food before they eat the food. Parker notes that the act of taking the photo of their food could sometimes mean users reflecting on their food before, or while eating it, implying that they are reflecting-in-action:

> *"It helped people take an extra beat—even if only for a second—to reflect on the foods they were eating.*" (p. 1746)

It should be noted, however, that there was a social factor at play here, also, which might have contributed to the reflective thinking. The app made users share the images of their food with others. A sense of social consciousness might have, therefore, contributed to the emergence of reflection.

4.3.2 Reflection and lifelogging

Lifelogging technologies are another form of device which are closely related to PI technologies. Discourse about lifelogging and the potential of lifelogging technologies to support reflection precedes Li et al.'s introduction of the concept of PI into the HCI lexicon. However, in recent years, interest in the former has subsided while in the latter it has grown.

This is perhaps because, while lifelogging has remained as something of a HCI vision, PI apps have been employed in practical, real-world applications. Nevertheless, some interesting themes emerged in the early lifelogging research, which provide a further insight into how people can reflect on personal information through their use of digital technologies.

The key difference between PI technologies and lifelogging technologies, is that while the objective with PI devices is to record data about life, with the intention of reflecting on the data as a proxy for the life-events, the ideal with lifelogging is to record life itself, and therefore revisit it in its original form. It's about replicating as much of life as possible in a digital form so it can be played back. This agenda was set by Microsoft research through their *MyLifeBits* project:

> *"MyLifeBits system is designed to store and manage a lifetime's worth of everything at least everything that can be digitised.''* (Gemmell, Bell, and Lueder 2006) (p. 253)

While there has been a lot of interest in the functional potential of these systems to record life e.g. (Gemmell, Bell, and Lueder 2006), there has been less discussion about what users should actually do with the recordings once they have been captured. Whereas in the PI field it has been clearly established that the data can serve as a source of knowledge, within the Lifelogging field, there has been little agreement on the utility of life logs. This has been highlighted by Sellen and Whittaker (2010) in a commentary on the state of the lifelogging research field, where they state:

> *"Many lifelogging systems lack an explicit description of potential value for users, focusing instead on technical challenges (such as data capture and retrieval mechanisms."* (p. 4)

However, studies have shown that one of the by-products of using lifelogging technologies is that they can support reflection. Harper et al. (2008) carried out a study where they asked participants to use Microsoft's SenseCam – a neck-worn camera that takes pictures frequently throughout the day. They asked participants to wear SenseCam then use the recordings to build narratives about their lives in a workshop, observing that the *strangeness* and *unexpected*

details of the recordings helped to trigger reflection. They suggest that this may have been because participants reinterpreted the past upon seeing it from a new perspective through the chest-level lense of the camera. One prominent theme is that participants didn't expect their everyday lives to have been filled with so many mundane activities such as driving and doing housework. Seeing these activities up-close from the perspective of the camera gave the smaller, less noticeable moments in life added meaning. This is captured nicely by a quote from one of the participants in the study:

> "*it actually goes into the life you're leading ... the boring bits where you're not achieving status ... they turn out quite interesting ... it focuses on the things we don't [normally] reflect on ... you make a slightly different judgement ... it can be really reaffirming, to look back on a really nice day and say, oh, it was ok ...".* (p. 274)

Harper et al.'s study provides evidence that exploration of SenseCam recordings can prompt reflection, but this process may have been a product of the workshop rather than a natural consequence of using the device. Participants were asked to select images and create narratives in a structured way during the workshop. It cannot be assumed on this basis, that they would do the same if they were using the device during their everyday life without outside intervention.

In a follow-up study, Harper, Lindley et al. (Lindley et al. 2011) decided to take a more hands-off approach and explored how members of households might use the *SenseCam* over an 18-month, longitudinal study. The households were interviewed twice; once after the first week and then again after 18 months. Members of each participating household were given a SenseCam each and a shared image folder where they could see each other's images; adding a social element. Once again there is evidence that participants reflected on their recordings when they were looking at and discussing them in interviews, but little evidence that they would do so independently in an uncontrolled setting. Harper et al. note that participants revisited recordings very infrequently across the study as a whole. Only half of those interviewed after 18 months (2/4 households) had revisited recordings since the beginning of the study and all stopped doing so after a few weeks.

This underlines the problem of the inaccessibility of lifelogged recordings. There is so much information to wade through, it becomes unwieldy and unappealing to engage with, as emphasised in (Sellen, Whittaker, and Sellen 2010). As highlighted in Kahneman's psychology work(Kahneman 2011), humans have evolved faculties which mean they don't have to process every small detail in everyday life; to do so, would be overwhelming. For the purpose of reflecting on experiences during everyday life, users might therefore be best-served by lifelogging systems that make it easier to review logs. Or alternatively, by other types of device, like personal informatics technologies, which package life-events in a more accessible form.

Harper et al.'s longitudinal study revealed an additional way in which users might reflect while using lifelogging devices. One of the participants in their study said that they felt more aware of their behaviour while they were wearing the SenseCam and were thinking about their actions more deeply than they might otherwise - "*it was truthful and it was honest but there was still a performance I felt to it, erm and that didn't cease during the course of the week*" (p. 14). Harper et al. associate this with Schön's (1983) concept of reflection-in-action. The user is intentionally changing the recording by adapting their behaviour for the camera. And it is through this element of *performance* for the camera that they reflect. There are some parallels that can be drawn between this form of reflection and the form of reflection that emerged from using Grimes Parker's (2014) study with the diet-tracking app, discussed above (page 111). They are similar in the sense that the user Is capturing the external event through a camera in both cases, and because in both cases they log the data while the experience is ongoing.

Harper et al. acknowledge that the emergence of this form of reflection may have been contributed to by the involvement of the research team. They speculate that if the research team had not said that they would be looking at the sense-cam images in interviews, the participants may not have reflected in this way. This underlines the sensitivity that users have to their own privacy and self-presentation when using lifelogging technologies. Privacy

concerns have been underlined as a broader issue within lifelogging research. Researchers have discussed how the constant presence of lifelogging devices in everyday life and the lack of control that users have over when it takes images, can leave users feeling exposed (Hodges et al. 2006; Nguyen et al. 2009).

4.3.3 Media-supported reflection

There is another group of technologies which are closely related to PI and lifelogging technologies, which have been variously labelled as devices for: *technology-mediated-reflection* (Isaacs et al. 2013)*, media-supported reflection* (Mols, Van Den Hoven, and Eggen 2020) *reflection on digital artefacts* (Thieme et al. 2011) and *prospective reflective systems* (Hollis et al. 2017). Although these labels all provide a slightly different emphasis, the technologies that fit under their umbrellas share the characteristic that they are all used for intentional creation and retrieval of *reflective* media.

Given that users record and revisit their experiences when they use these reflective media devices, they are used in a similar way to PI tools. What separates the two types of device, is that reflective media devices don't have the kind of data visualisation that characterises PI devices; where multiple pieces of data can be revisited and compared simultaneously from the single display. They are tools for users to re-experience and reflect on digital mementos individually, rather than for developing self-knowledge by analysing relationships between data from multiple experiences.

The *Echoes* app, designed and implemented in research by Isaacs et al. (2013) is often cited as a classic example of a technology for media-supported reflection. This app was designed to purposefully scaffold reflection through its interaction design. Periodically, users of *Echo* are presented with photos they have taken in the past and are asked on the interface to rate how happy the memory is and '*write a reflection'*. Isaacs et al. don't discuss what constitutes

reflection in their study and there seems to be an implicit assumption in their paper that reflective *writing* constitutes *reflection, suggesting that reflection just requires the individual to look back and describe an event from the past*. Nevertheless, they describe some scenarios from a user study, which indicate that users may have been reflecting on their experiences when they used the app. An example is a participant in their user study who took a photo to represent how angry they were with their boyfriend, but who then wrote a more empathetic reflection about this photo the next day. The consideration of the event and shift in perspective indicates reflective thought.

Isaacs et al. suggest that time plays an important role when users reflect on media with the Echoes app. They cite psychology literature by Mitchell et al. (1997) to suggest that over time negative feelings fade as users naturally orient themselves to a rosier outlook on events from the past. They use this argument as a basis to suggest that encouraging users to reflect on media from the past can support wellbeing, by fostering a more positive outlook on events.

Isaacs et al.'s approach to reflective media is structured and controlled. Users are directly encouraged to reflect on experiences from the past by the Echoes app. Mols et al. (Mols, Van Den Hoven, and Eggen 2020) have demonstrated a more hands-off approach. They implemented three different tangible reflective media devices*, Dott, Cogito and Balance* in a 6-week field study, through which they aimed to explore the concept of *Life Reflection*. Mols et al. define *Life Reflection* as, "*remembering plus further analysis*." (p. 68) Given the emphasis on looking back into the past and remembering, there is a similarity with Isaacs et al.'s inferred interpretation of reflection. There is no suggestion by either Mols et al. or Isaacs et al. that reflection must involve a change in perspective.

Unlike in the Isaacs et al.'s study, users weren't explicitly told to reflect when using the device. The systems just provided *opportunity cues* - ambient lighting indicating the possibility of engagement. One of the observations taken from interviews with participants who took part in

their user study, is that users tend to reflect more often when they create media than when they revisit it. This contrasts with Isaacs et al.'s paper, where re-visitation of the media is framed as the focal point of reflection. Mols et al. also observed that users in their study had a tendency to reflect on experiences from the near-present. They note one participant, in particular, tended to reflect on what had happened *today,* even if media represented something else from the past. This indicates that users have a preference to stay focused on what is most currently relevant. At the same time, however, Mols et al. note that participants rarely used the devices during the flow of everyday life. They would use them at the end of the day or in a moment of downtime, when they were at home. This means they weren't necessarily engaging with experiences directly, as they were happening, but were looking back across a day when it was convenient to do so.

Mols et al. also discuss how the design characteristics of their prototypes affected the way users engaged and reflected on their experiences. They note that participants tended to reflect more deeply when they used the sound and text modalities and in a lighter-hearted way with the photo-based app. They suggest a link between the attentional demands of the media-creation task and the depth of reflection, because capturing a photo could be done in the most off-hand, thoughtless manner of the three. They also note that recording or revisiting sound media in public made users feel exposed; privacy concerns that mirror conclusions drawn by Sas et al. (2015) and Dib et al. (2010) in similar studies.

4.4 Summary

This chapter has outlined how reflection has been defined outside of HCI, how it has been conceptualised and modelled within HCI, and how it has been applied in PI research. This has highlighted that while there is a basic understanding *that* users reflect when they log data and when they revisit data displayed on their phone - the latter of which has received the most attention - there has only been a limited attempt to explain *how* they reflect. Three key aspects of this to that be investigated in research are now summarised below:

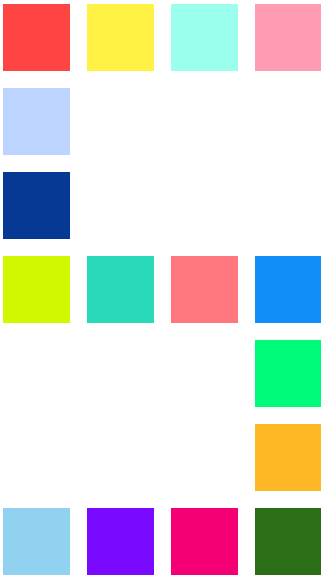
- *How PI technology design affects the way users reflect:* As already summarised above, users appear to reflect both at the time when data is logged and when they revisit it on a display. In PI literature, reflection when users revisit data has been described as a process of them looking at data displayed on the device and drawing insights from the relationships, or trends within it. Reflection at the time of logging has been described as either emerging from engagement with real-time feedback from a device during an activity, or from the act of manually logging data on the device. Explanations for how these processes unfold are high-level and lack some nuance. Further investigation into the effect that different types of data (e.g. the colour data implemented in the *SpriteCatcher* study), and different ways of logging (e.g. capturing colours from the environment) and displaying it (e.g. on a minimalist display), might have on the way users reflect, could provide a more detailed picture of how the interaction design of PI devices affect the way users reflect.

- *Reflection as a fundamental shift in perspectives:* Reflection has been defined in various different ways. Its interpretation often seems to be adapted to the context in which it is being used. One example of this is that in papers from the *technologies for media-supported* reflection field, a domain in which remembrance is important, it has been interpreted so it emphasises this. In the PI field, although there isn't an explicit agreed definition for reflection, there seems to be a general underlying assumption that it is a process that involves deep consideration of the basis of perspectives resulting in a fundamental transformation of those perspectives; as Li et al. put it, bringing people a "*newfound understanding of themselves"*. It is understandable that a definition which

emphasises transformation of knowledge would underpin the PI field, given that there is such a focus on designing technologies for behaviour change. This kind of interpretation of reflection is useful because transformative thinking can catalyse behavioural change. However, literature suggests that reflection doesn't necessarily have to involve a shift in perspectives. And if the focus is on designing PI devices for self-knowledge as an end-goal or simply for general experiential engagement during everyday life, the notion of reflection as a transformative process becomes less relevant. It bears asking, therefore how reflection should be interpreted when it is in service of these other more subtle outcomes.

- *Types of reflection*: There has been little attempt in PI literature to formally describe different types of reflection in PI literature. The one formal categorisation that has been made is to define instances of reflection either as *reflection-on-action* or *reflection-in-action*. Reflection when revisiting data has often been associated with reflection-on-action and reflection through data logging as reflection-in-action. It would be beneficial to build a greater understanding of how different forms of reflection emerge from different forms of interaction and how we might detect and categorise them through HCI research. Schön's concepts of reflection-in-action and on-action (Schön 1983) provide a useful guide for this, as does Fleck and Fitzpatrick's framework of reflection (Fleck and Fitzpatrick 2010), which provides a way to articulate different forms and sub-processes of reflection.

The next chapter explores these issues, through the implementation of a field study, as a means to understand how design characteristics of a minimalist flexible experiential logging technology can affect the way users reflect. While doing so, it carries on the broader discussion about how users log and engage with the meaning of experiences when they use experiential logging devices.



5. Reflection with experiential logging technologies: An investigative field study

The previous chapter (Chapter 4) set out how reflection has been defined inside and outside of HCI, in particular focusing on how it has been framed in literature relating to PI research. The process of developing the background knowledge necessary to write the literature review, has provided a foundation for us to now carry out a more targeted investigation of how users reflect when they use minimalist, flexible experiential logging devices than was possible in the *SpriteCatcher* study from chapter 3.

In addition to investigating how users reflect on their experiences, the research described in this chapter builds on the work in chapter 3 by furthering the exploration of how flexible, minimalist design characteristics might affect the way they engage with their experiences during everyday life. A prototype experiential logging app, *Chromatize*, was developed which was given to a set of 11 participants to try out in a user study. As a means to probe the different effects of minimalist and flexible design on users, various different versions of the app were developed which provide users with different ways of logging and revisiting data. Participants used the app for six weeks, experiencing the different functionality of each version in turn. Their experiences were evaluated, in detail, through a range of rich data collection methods.

The chapter is organised as follows: First the design motivations and the features of the *Chromatize* app are outlined (*5.1*), second, the research approach and study procedure are described (*5.2*). The chapter ends with the research findings (*5.3*), and a short summary of the key discussion points within the findings (*5.4*). A full discussion of the findings, setting them in the broader context of the project, is in the next chapter (Chapter 6, page 194).

5.1 Design motivations

Chromatize is the app that was implemented to further the research into reflective practices with minimalist interfaces for experiential logging. The *Chromatize* design is driven by the motivation to develop a simple, easy to use device that supports meaningful engagement with experiences during everyday life.

There are two key design characteristics that the *Chromatize* app shares in common with *SpriteCatcher*, as a means to build on and clarify the knowledge developed through that research study:

1. The *data type* that users log with the device continues to be based around colour. In chapter 3 we discussed how colour as the form of data that users log appeared to support flexible, meaningful engagement with subjective experiences, with a special emphasis on emotion. We also observed that when users logged colour data with the *SpriteCatcher* device it had a transient quality, where it lost its meaning quickly. By retaining colour as the data type and changing other design characteristics we aimed to draw a comparison between different design approaches and assess how they affect the way users engage with colour data.

2. The data display remains minimal and will only show the last *four data entries* logged. Although the *SpriteCatcher* data display served as a form of feedback in study 1, it appears that participants took little notice of their previously logged colours. By retaining the minimalist display design and changing other design characteristics, we aimed to draw comparisons and assess how different factors affect whether, and how users engage with a minimalist data display.

The *Chromatize* design also has a number of new design features, listed in this next section, that separate it from the *SpriteCatcher* device. In some cases these decisions serve a

methodological purpose, providing a means for richer data gathering and for closer inspection of how design affects the way users interact. In other cases, they are a direct attempt to address issues that participants had with the *SpriteCatcher* device that was implemented in chapter 4: The way that it tended to be cumbersome to carry around and use during everyday life and tended to make users feel self-conscious because of its indiscrete, unfamiliar design.

5.1.1 Design changes

Mobile app as the form of the device. a mobile app was opted for, designed to emphasise discretion and simplicity. Mobile apps are naturally adapted for discretion because of the ubiquity of mobile phones. It is common to see people using them in public, meaning users might not feel so socially aware when interacting. Switching to this form of interactive system may have implications for how users log and reflect. In particular it is interesting to assess how it might influence when users log; the assumption being that a more discrete and convenient system might be more conducive to logging during everyday life.

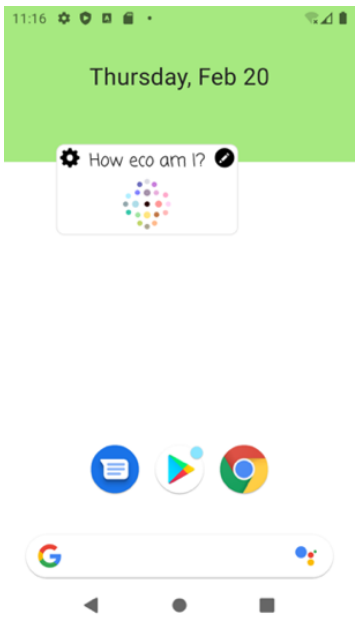


Figure 8. Chromatize widget on phone homescreen

To make the app as easy to use as possible, its functionality is built into a widget that sits on the home screen of the user's phone. Self-tracking apps tend to require users to navigate through different interfaces to access functionality. The advantage of a widget makes functionality immediately accessible from the home screen, (
Figure 8, below). This approach builds on the widget-based design approach demonstrated by Choe et al. (Choe et al. 2015) with their *SleepTight* PI app; first discussed in chapter 2 (page 35). Attempts were made to ensure that *Chromatize* widget had a simpler, more minimalist design so as to be more discrete.

***Explicit topic setting*:** *Chromatize* was designed so users have the capacity to set a topic, which is then displayed directly on a widget on their home screen. Letting users set a topic helps with data collection because it provides an opportunity to scrutinise how users engage with the meaning of their experiences when they log. The app collects data about which topic users set and when they change their topics.

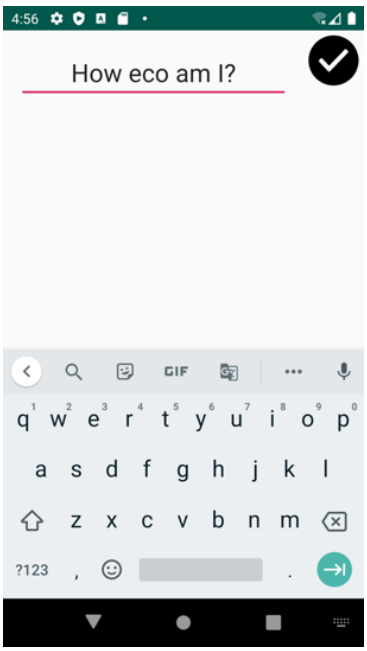


Figure 9. Chromatize topic setting interface

Users can, at any time, set a topic for what kinds of experiences they are logging. They go to the settings interface by tapping on the cog symbol on the widget (
Figure *8*, above). This brings up the settings interface, where they have the option to type-in and then confirm a topic by tapping on the check mark (

Figure *9*, below). This is then added to the widget on their phone's home display (
Figure *8*, above).

Data displays: It was decided to put the *Four Data-Piece Display* on the home screen of the phone by embedding it into the user's home screen wallpaper (Figure 10, below). This means that it sits in amongst all the other features of a phone's home display, behind the app icons. This design decision was motivated by the aim to make the data display as easy to access as possible. The user would be able to look at their data directly from the home screen without navigating into an app.

Figure 10. The last 4 colours logged are displayed on the background of the home screen of the phone

Once again, this design decision, builds on the minimalist PI design approach demonstrated by Choe et al. (Choe et al. 2015) with their *SleepTight* app. Except that rather than having the display positioned within the confines of the widget, it is integrated into the background wallpaper of the phone. This is possible because colour, while being the data type, also has an aesthetic quality which lends itself to being used in this way. The four-colour display can blend-in subtly and serve as background wallpaper more effectively than other types of data or styles of display, such as the numerical chart data featured on Choe et al.'s widget.

The app also features an All-History Data Display, which shows all previous colour data entries logged chronologically (Figure 11, below, image 2). This display is read as a timeline from right-to-left and from bottom to top, so that the most recently logged colour is in the top left-hand corner of the interface. Each time the user logs a colour, a colour-block is added to the timeline. If they log the colour on a new day, a day-block is added to the timeline and if they change their topic a topic block is added to the timeline.

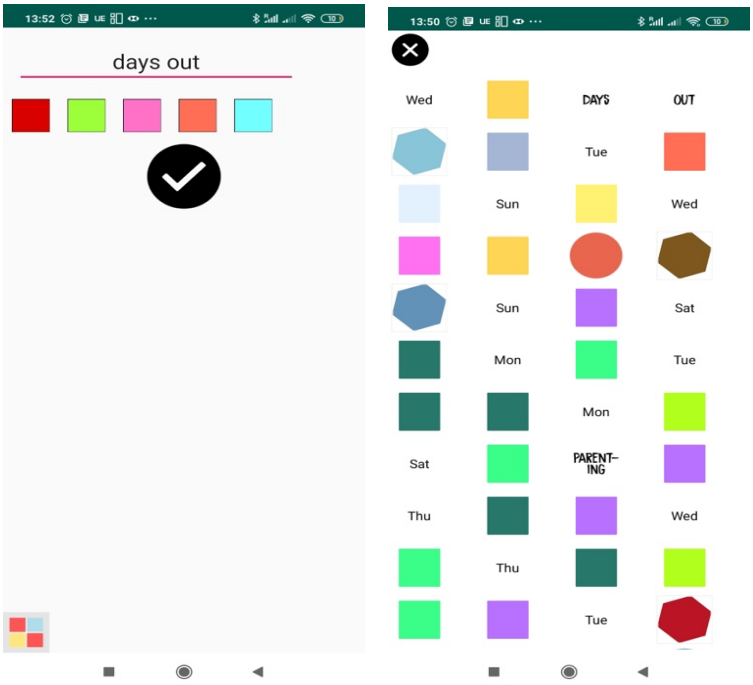


Figure 11. Image 1 - All History Display access button (bottom-left), Image 2 - All History Display

This means that users can see what colour they logged, when they logged it and what their topic was at the time when they logged it. This additional display, which is accessible by navigating to the settings interface (cog button,
Figure *8*, above) and then by clicking on the coloured square button in the bottom-left corner of the settings interface, was only made available to users in the second half of the study (weeks 4-6). This was so the way users engaged with each of the displays could be compared.

Three logging methods: Users can log data with *Chromatize*, either by selecting from a small colour palette whose colours can be pre-set by the user (p. 128) selecting from a large colour palette with a fixed set of colours (p. 128) or capturing the colour from the environment using a camera-style interface (p. 128).

First, the provision of these three logging methods was motivated by the desire to explore modes of data logging that might be simpler to use than the one that was trialled in chapter 4. Second, it was motivated by a desire to compare how users might engage with their experiences when they log through different forms of interaction. Each of the three puts different constraints on the user, in terms of which colours are available for them to choose from at a given time, and what they need to do to choose one, both of which may affect the way participants log and reflect on their experiences. To aid the comparison between them, participants in the study were given access to each of the logging methods individually in turn during the first 3 weeks of the study (weeks 1-3) and then given access to an *All* version in the final three weeks (weeks 4-6) where they could access all three of the logging methods. The order that users received different versions was counterbalanced across the group.

Pre-set palette logging method

Users can log a colour with a single button press. They simply tap on one of the colours on the widget to log it (Figure 12, *image 1*). Users can pre-set the colours available to them on the widget at any time. They navigate to the settings menu (cog button) and set 3-5 colours using the palette (Figure 12, *image 2*), clicking on the check icon to confirm.

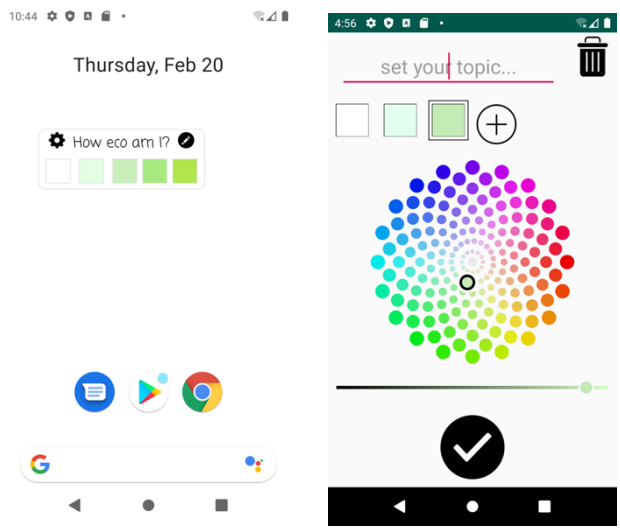


Figure 12. Pre-set palette data logging interface

Large palette logging method

Users can select any hue from the large palette with three button presses. They tap on the large palette icon on the widget (Figure 13, *image 1*). This takes them to the large palette selection interface, where they then choose a colour (Figure 13, *image 2)* by tapping on it, before pressing the check mark to confirm. There is a slider for modifying the brightness of the colour

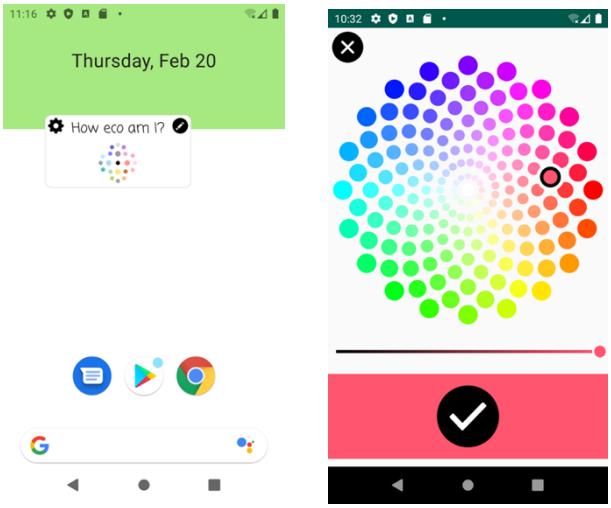


Figure 13. Large palette data logging interface

Capture logging method

Users log a colour with three button presses. They tap on the camera shutter icon on the widget (Figure 14*, image 1*). This opens the camera lens, taking them to the colour capture interface (Figure 14*, image 2*). The display shows whatever the phone's camera lens is pointing at, like a typical camera application. However, instead of taking a photo, the user taps on the display to capture a colour. When they tap, the colour on the screen, where they tapped is added to the box at the bottom of the interface. Tapping on the check symbol then logs the colour. In the example image (Figure 14, *image 2*), you can see that the user has captured the green colour from their TV screen.

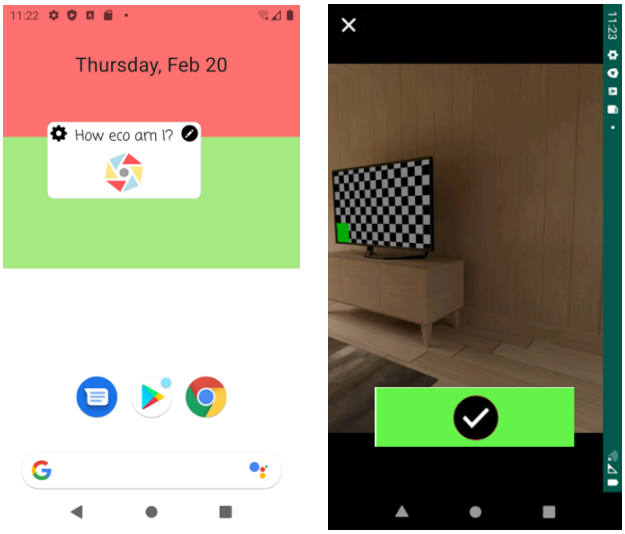


Figure 14 Capture data logging interface

All logging methods

There is one final version in which all of the different logging methods described above can be accessed through the single widget. The widget has all three button icons, for accessing the large palette and *capture* interfaces and for directly logging one of the *pre-set* colours (Figure 15).

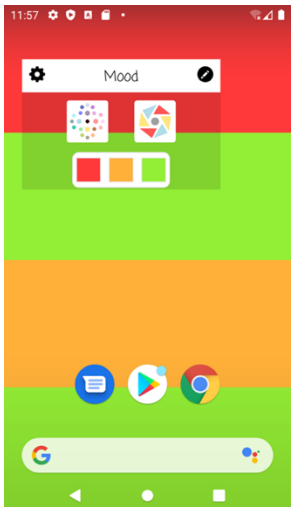


Figure 15. All data logging interface

5.2 Method

The research approach in study 2 shared some characteristics with the study 1 approach. Like in study 1, it involved an in the-wild user study with qualitative data collection. Participants were interviewed, after having been given the freedom to appropriate an experiential logging technology for use in their everyday life, outside the laboratory setting. Once again explorative, open-ended research methods have been employed because they were considered to be best-suited to the aims and the context of the research. Study 1 showed that giving users the space to use the device and then freely report on what is meaningful for them in interviews can help to provide access to the nuances of subjective experience. An approach that we chose to build on here.

Study 2 differs from study 1, however, in terms of its length and scale. It is a longer duration, six-week study, compared to the three days of study 1; which provides for richer data collection. Over six weeks there is a better opportunity to observe the persistence of phenomena over time, providing more concrete evidence to justify the claims. It also means the context of use being focused on in in the study, i.e. *everyday life*, better reflects the social context that is being targeted by the research questions. It has been noted that there can be a *reactivity effect* in the first few days after participants receive a new personal informatics technology. Clemes and Dean (Clemes and Deans 2012) have observed that there is a marked increase in engagement, and in the effects of using activity tracking devices, in the first week of use compared with subsequent weeks. Carrying out the study over six weeks was intended to allow such a reactivity effect time to wear off and for technology-use to become more integrated into everyday life. In particular, the last three weeks of the study, when there were no methodological interventions and participants were left to freely use the app, was intended to mitigate this effect.

5.2.1 Participants

11 participants took part in the study, recruited through personal contacts. When contacted by email, the participants were asked if they would like to take part and given a brief summary of what was involved – to "*try out an experience logging device for 6 weeks and discuss your thoughts about it*".

The participants had a range of different profiles (Table 5, next page) All of the personal information in the table, apart from that in the *other notable characteristics* column*,* was collected directly from the participants when they filled out a brief questionnaire at the *study-setup meeting*. *Other notable characteristics* are observations that were picked up informally by the researcher in the interviews through the course of the study.

Name	Age	Occupation	Self-tracking/ diary experience	Other notable characteristics
P1	25	Computing PHD student	Tried my fitness pal but stopped using it. Agenda, future plans list – includes some elements of personal life	Enjoys listening to music
P2	60	Retired	None	Enjoys going for walks, the outdoors.
P3	30	Programme support co-ordinator for NGO	Fitbit-for tracking steps and running. *Task planning*	Travels abroad for work often. Worked abroad on the third week of the study
P4	28	SEN teacher,	None	Keen horse-rider.
P5	26	Marketing	Fitbit, Nike Running, MyFitnessPal, Task lists Wedding planning	Planning marriage next summer
P6	28	School Teacher	Tried FitBit. MyFitnessPal but didn't sustain	On school holidays in the first week of the study
P7	33	Brands Insight Manager	None *Task planning*	Has a 4 year old son
P8	28	Computing PHD student	Fitbit, Google Health, Huawei Health for sleep tracking	Keen Manchester United fan
P9	21	Singing Teacher	None	Moved to London during the study to join parents as COVID 19 emerged
P10	21	Music Masters Student	None	Moved from UK to Japan during the study to join parents as COVID 19 emerged
P11	30	Online Marketing/ SEO manager	None	Enjoys home-cooking

Table 5. Chromatize study participant profiles

5.2.2 Data collection

There were two different sources of data gathering in the study: Qualitative data gathered through interviews and quantitative data gathered through data collection by the app itself.

Interview approach: Study 1 demonstrated that semi-structured interviews, based on open-ended questioning can be an effective method for assessing how users might engage with the meaning of their experiences through the use of a minimalist experiential logging device. Participants readily expressed what kinds of experiences they were logging, the colours they logged and the meaning they might have drawn from these processes, providing rich data about their logging behaviour and experiential engagement.

This approach was built on here, in this second study. Each participant was interviewed four times and at the beginning of each interview they were asked to speak openly about their experience of using the app. This was purposefully intended as a way to get them to freely report about what was meaningful to them. They were also asked why they chose to use the device to log colours and whether they ever recall having looked at the colour display on their phone. If they said yes, they were asked to describe why they did this. If applicable, they were also asked to compare the version of the app they had just been using with one they had used in the previous weeks of the study.

In the final interview, in week six, there was generally more attention to the unpicking of details of their experiences. Participants were asked to describe examples of what experiences they logged and why they chose to log them in the way they did. As a prompt for these discussions, participants were asked to get out their phone and discuss the colours it showed.

See appendix III (*page 247*), for the full list of questions that were prepared as a general guide for the interviews.

Using the physical prompt of the display was designed to help aid recall. There are a number of factors which affect how well a person can accurately recall the details of experiences from the past when being interviewed, including the extent they focus their attention when retrying to recall the experience (Schooler 2002) and which contextual associations they focus on when doing so (Marian and Neisser 2000; Smith and Vela 2001). Therefore, in interview 4, a technique known as the *second-person interview method*, was also applied. As Petitmengen, who established this technique writes, it is specifically designed to aid recall of the nuances of experiences:

> "*An interview method which enables us to bring a person, who may not even have been trained, to become aware of his or her subjective experience, and describe it with great precision."* (Petitmengin 2006) (p. 229)

According to Petitmengen this can be achieved through the scaffolding of attentional focus toward contextual cues. The role of the interviewer is to guide the user's focus to the perceptual phenomena that they experienced during the event they are trying to recall, helping them to remember the details. They do this by going through a process where they first draw the interviewees attention to sensory, contextual cues from the memory by asking questions focusing on what the individual could see, hear or smell. This is called moving them into an 'evocation state'. Then, once they see behavioural signs that the interviewee is in this state, e.g. eyes focused upwards and away from the interviewer, the interviewer uses content-empty questioning to guide them through the experience chronologically, e.g., *Talk me through what happened first, what happened then*?, and by repeating what the interviewee said back to them. After going through this preparation process, the interviewer can then ask more specific *how* questions, to deepen the level of thinking, e.g. So *how did that happen?*, in effect drawing out their perspectives from the time rather than a post-hoc representations

It is acknowledged that this form of interviewing may take considerable skill and experience to execute effectively, sometimes requiring months of practice for mastery. In the context of this research project, the goal is to draw on elements of it rather than to master and execute it

comprehensively. As such, the interviewing approach deployed in this study should be conceived as a second-person *inspired* technique, rather than *the* second-person technique applied as Petitmengen imagines it. Furthermore, this style of questioning was only applied for a short period of the interview, toward the end.

Direct data collection: There were two forms of direct data collection that were carried out through the app itself – usage data and experience sampling data. These data streams were intended to augment and triangulate the interview data.

> *Usage data*: The app collected data for which colours users logged, when they logged them and which of the three logging methods they used. It also collected data for the topics they set and when they set them.

> *Experience sampling data*: Survey questions were submitted to participants periodically when they used the device through an experience sampling questionnaire interface. This form of live-data capture provided a way of obtaining data about participants' interactions perspectives while they were using the app. As Berkel et al. (2017) have suggested, experience sampling facilitates the collection of rich data about micro-interactions that are otherwise difficult to access when users are interacting with mobile phones outside the laboratory. This attribute is particularly valuable given that the focus of this study is on fostering short, fleeting moments of interaction during everyday life, which are likely to be particularly challenging to access.

The design of the micro-experience sampling system was modelled on the one that Ferreira et al. (Ferreira et al. 2014) have demonstrated. The app proposes context-sensitive multiple choice survey questions based on a series of pre-set rules (Table 6, below) that are programmed into the device. Participants receive questions at different times and under different conditions depending on their behaviour and use of the app. This makes it possible to

target the participant with more specialised questions that penetrate deeper into the nuances of user experience than a one-size-fits-all approach would allow. At the same time the system is designed so there is an onus on simplicity and seamlessness. The questions are multiple choice so the participant can respond to them quickly without overly disrupting the flow of their phone-use. The experience sampling survey pops up automatically when participants log colours. Which question they receive is determined by the aforementioned question-trigger rules.

To respond to questions, participants select one of the multiple-choice responses by tapping on a radio button. If they select other, they can type in extra details in a free text-entry format (Figure 16, below). If there are multiple questions, the arrows can be used to cycle through them. The final question has a green check mark rather than an arrow symbol (*image right*), to indicate that the responses are being submitted. Participants are given the opportunity to cancel their responses by pressing on the 'x' symbol. See appendix IV (p. 248), for the questions and multiple-choice response options.

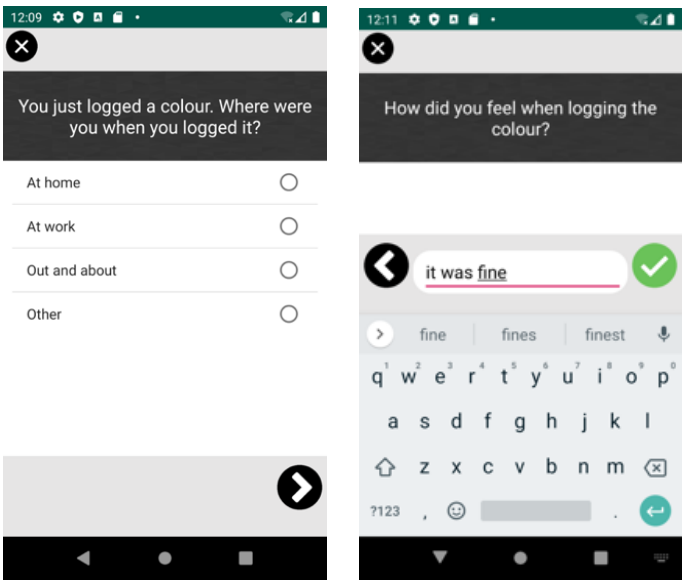


Figure 16. Experience sampling interface. Multiple choice question format (image 1) and free-text entry question format (image 2)

Question ID	**Schedule Condition**
A Logging a colour	**IF** the user logs a colour **And** hasn't responded to this question in the previous 3 days
B Inactivity	**IF** the user hasn't interacted with the app in the previous 4 days
C Topic setting	**IF** the user changes their topic **AND** hasn't responded to this question in the last 3 days
D Changing Pre-set colours	**If** the user is using the "Pre-set palette" widget **OR** the "All" widget **AND** changes their pre-set colours **AND** hasn't responded to this questions in the past 3 days
E Comparing logging methods (weeks 1-3)	**IF** it is between week 1 and week 3 in the study **AND** the user logs a colour **AND** the logging a colour question is not active **AND** the user hasn't responded to this question in the previous 4 days
D Comparing logging methods (weeks 4-6)	**IF** it is between week 4 and 6 in the study **AND** the user logs a colour **AND** the logging a colour question is not active **AND** the user hasn't responded to this question in the previous 4 days

Table 6. Experience-sampling trigger rules.

5.2.3 Procedure

In advance of the study, ethical clearance was gained through the university to ensure that ethical practices were followed for the collection, storage and reporting of personal data. Each participant was invited to a study-setup meeting and sent a consent form to verify if they would like to take part. This was developed as part of the ethical clearance process. It contained a broad summary of the study process and asked consent for data collection and storage (the audio recordings taken during the interviews and the usage data and experience sampling data downloaded from their phone). Participants were given license to remove

themselves and their data from the study at any point, up until an agreed data, and were informed about the length of the study, how many interviews were involved and their approximate length. They were told that they would receive a £25 voucher as recompense for their participation - as part of the ethical clearance process it was decided that compensation was necessary given the degree of effort required, but the amount was kept relatively low to limit the extent to which it might influence participation.

At the study setup meeting, participants were familiarised with the concept of *experiential logging with colour*. They were asked if they currently used any technologies to record any aspects of their life; *Fitbit* was given as a typical example to open the discussion. It was then explained that in this research study, the intention was to explore an alternative approach to PI, where the idea was to use colours to record experiences. The participants were told that given that this was a new idea, which they might be unfamiliar with, we would explore some scenarios for how this might work together before looking at the device.

First, the participants were asked to choose a topic, which would serve as an example in the scenario. They were given a list of example topic ideas as a stimulus, which were taken from HCI PI research literature.

Once they had chosen an example-topic, the participants were presented with a pack of 100 Pantone colour cards. These had been roughly pre-arranged into an ordered pile so cards with similar hues were together. The participants were asked to think about the different features of the topic they had chosen and consider the different ways they could associate colours with these features by picking out coloured cards and arranging them in such a way as to characterise the topic. They were asked to explain their thought process while doing so.

This process was carried out 2 more times, to further familiarise the participant with the idea of associating colours with experiences. The participant was then asked to take out their phone so the app could be installed on it.

As described above, the app features 3 different logging methods (p. 128) and two different displays (p. 125). The participants only had access to certain features at a given time in the study. They received access according to a planned procedure through the course of the study (Table 7, below).

To explain this process, the study can be separated into two parts. In part 1, (1-3 weeks), the participants had access to one of the Pre-set palette, large palette or Capture versions. Which one of these they had access to changed each week (the order in which they received them was mixed proportionally across the participant pool - *A-B-C, B-C-A, C-A-B* - to mitigate ordering bias). Then for part 2, the remaining 3 weeks of the study they used the *All* version of the app (p.129), with which they could access all the different logging methods simultaneously.

Additionally, in part 1, the participants only had access to the *Four Data-Piece Display* and during part 2, both displays.

Study period	Availability of logging methods	*Availability of displays*
Part 1 (weeks 1-3)	• *The Pre-set palette version* (week 1, 2 or 3) • *The large palette version* (week 1, 2 or 3) • *The Capture version* (week 1, 2 or 3)	• *Four Data-Piece Display available*
Part 2 (weeks 4-6)	• *The All version* (weeks 4-6)	• *Four Data-Piece Display available* • *All-History Data Display available.*

Table 7. Availability of logging methods and displays in different periods of the study

This 2-part structure was implemented because it would provide a way to address the research questions in a targeted, investigative fashion in part 1, and to provide a more open exploration of the research in part 2. The first part (weeks 1-3) is a within-subjects controlled procedure. The participants received the logging methods in a controlled, pre-structured order so comparisons could be drawn out between them in the interviews - providing a direct insight into how different logging methods affect the way users log and reflect on their experiences. The second part of the study was designed to be much less intervention-heavy. There were no interviews or changes in experimental condition and participants were left to use the app more freely and integrate it into their everyday life. It was less controlled and more of an in-the-wild experimental approach. It was therefore intended to serve as a more realistic simulation of everyday technology-use.

Meanwhile, the *All-History Data Display* was held back until the second part of the study so a comparison could be made between the way participants used the two displays. The participants were given access to the *Four Data-Piece Display* for the whole study because,

given the interest in minimalist data displays in this project, this display was the main focus. Providing the *All-History Data Display* part way through, however provided an opportunity to inspect the amount of value that users put on the minimalist display approach. Asking the participants to compare the two displays in the interview and examining whether they adapted their approach to accommodate the *All-History Data Display* part way through, would provide an insight into this.

Three short interviews of 15-20 minutes were conducted with the participants over the phone at the end of weeks 1, 2 and 3. A longer interview of 45-60 minutes was conducted in-person at the end of the 6 weeks. At the end of each interview the participant was asked to send the usage data and experience sampling surveys from their phone, using a data-transfer function pre-programmed into the app. Through the course of this study, this data was checked over informally between interviews to ensure that the app was functioning correctly.

5.2.4 Analysis

Once the participants had completed the study, the usage data and experience sampling data were organised so that it could inform thematic analysis of the interview data. Timeline charts were created, showing which colours each participant logged, when they logged them, which logging method they used and when they changed topic; providing an overview of their logging behaviour over time. The experience sampling data was compiled into charts depicting the frequency of each survey response.

To begin the thematic analysis process, the interview recordings were all transcribed. The organisation of themes in the thematic analysis process was similar to the process described for the first study (Chapter 3, page 66), which itself was based on the model described by Braun and Clarke (2006) - an iterative process of organising the data into themes by linking them by theme, verifying these themes with other external researchers, re-calibrating themes and verifying them again. A key difference, however, is that the process in this research study was

not as purely inductive. In this study the aims are more refined. As such the analysis process is more deductive, based around the following key themes:

Reflection – *Do users reflect? If so, how do they reflect?*

Logging behaviour – *which topics participants choose to set*, *when participants log, what prompts them to log, and how they decide which colour to log*

Design characteristics – *How the participants compare the different app versions, why they chose to use one version over another in weeks 4-6, how the design characteristics affect the way users log and reflect.*

However, while these themes were a basis for the grouping of the data, it wasn't entirely constrained by these themes. There was also an element of flexibility to the coding. Themes that didn't fit with these specific areas of interest described above, but which seemed relevant because they expressed something important about the way that participants engaged with their experiences, were taken note of. Any chunks of transcribed interview that resonated in this way were initially fitted into a category label *other* so they could be returned to and unpacked in the next iteration of the analysis process.

Once the data had been sorted into initial themes it was submitted to a group of three other researchers who together carried out a '*sanity check'* to verify its logic and consistency. The usage data timeline charts were also shown to this party to aid a broad discussion about patterns in the data and how different users engaged with their experiences while using the device. On the back of these discussions, the themes were adjusted to rectify inconsistencies and the theme titles were refined to increase their accuracy. It was also at this stage that themes in the *other* category were pulled out and subjected to more granular analysis. Where possible, they were accommodated in the newly adjusted theme-set or else new themes were created to accommodate them. The full set of themes were then submitted to the secondary researchers once more for a second iteration of the verification step. This prompted discussion

about any additional adjustments that might be necessary, and decisions were finalised about the titles and content of each theme.

The analysis of themes relating to reflection was carried out in light of the literature that was reviewed in the previous chapter. As set out at the end of that chapter, pg. 118, reflection has been interpreted as a process that involves both the consideration of, and a change to, knowledge or beliefs. To establish *if* users reflected when they used the device and how these two processes played into this, it was important to therefore group data according to whether it describes consideration of meaning alone or consideration of meaning and a change in knowledge and beliefs.

5.3 Findings

Section 5.3.1 of the findings reports on **logging behaviour.** It begins with a *broad overview* of how the participants, as a group, used the app to log their experiences across the six weeks of the study. This is followed by a set of *logging timeline profile charts*, presenting the colours logged by each participant individually. These charts help to depict the different ways that the participants structured their logging. Section 1 ends by laying out what prompted participants to log colours.

Section 5.3.2 reports on findings categorised as relating to **reflection**. This covers the *topics*, or types of experiences that participants chose to focus on in the study, how users engaged with the meaning of their experiences when they used the device and how it might have affected their perspectives and beliefs. This is the first step in reporting these findings. The next step, evaluating where the different examples of reflection fit into Fleck and Fitzpatrick's model is reserved for the next chapter (chapter 6).

Section 5.3.3 reports on findings categorised as **design characteristics.** This covers the role of *colour*, as the symbolic form for expressing experiences, the different perspectives and preferences that the participants had with regards to the three logging methods and their perspectives on the data *displays.*

It's important to acknowledge that the three categories are linked; how users log, how they reflect, and the design characteristics of the interface all have an influence on each other. As such, in a number of cases, the themes placed in one of the categories could easily have been placed in another. The final decisions taken are based on what was considered to be the best fit for making the data digestible, rather than the only fit. This approach was intended to set a basis for the *discussion* where the relationships between *reflection, logging behaviour* and *design characteristics* are pulled out.

5.3.1 Logging Behaviour

Across the study participants logged a total of 555 individual colours. The logging data from their phones, paired with their responses in the interviews indicates that most participants engaged with the study, continuing to log colours throughout (Table 8: Number, range and mean number of data pieces logged by participant and week). None of the participants dropped out of the study entirely, although some did experience short periods during which they participated less actively, or at least differently. These are the particular outliers in the table below (next page):

- P11 logged no colours in week 2 because his phone screen broke;
- P4 logged no colours in weeks 4-6 because she had fallen from her horse, which stopped her wanting to log;
- P3 logged no colours in week 3 because he was on a busy work-trip in Thailand;
- P2 in week 3, logged no colours in week 3. However, this misrepresents her engagement because she was logging in a different way - by changing the pre-set colours on her phone.

	Week 1	***Week 2***	***Week 3***	***Week 4***	***Week5***	***Week 6***	*Mean*	*Range*
P1	5	9	13	13	7	6	**8.3**	**8**
P2	12	12	0	14	2	2	**8.4**	**10**
P3	5	6	0	4	5	2	**4.4**	**4**
P4	9	10	8	0	0	0	**5.4**	**2**
P5	10	5	11	12	4	1	**7.2**	**11**
P6	5	4	5	3	2	3	**3.6**	**3**
P7	10	8	6	3	2	1	**3.8**	**9**
P8	32	7	13	7	7	4	**11.6**	**28**
P9	17	13	11	9	4	3	**9.5**	**14**
P10	12	7	4	4	3	4	**5.6**	**9**
P11	22	0	14	8	9	9	**12**	**6**
Mean	12.6	7.4	7.7	7.0	4.1	3.2	9.4	7.3

Table 8: Number, range and mean number of data pieces logged by participant and week of study

Across the participants, as a single group, there was an overall reduction in logging frequency over time (Figure 17, below). There appear to have been noticeable spikes on days 1-2, 7-8, 15-16 and 22-23, which can be related to the *reactivity effect*. In the final three weeks of the study, when there was no experimental intervention, some participants sustained a higher and more consistent logging frequency than others. P1 and P11 are two notable examples of participants who maintained their logging more than others. P2 and P5 are notable for the sharp drop-off in their logging. Apart from P4, who had a specific reason for having stopped using the device, the participants all logged at least one colour each week.

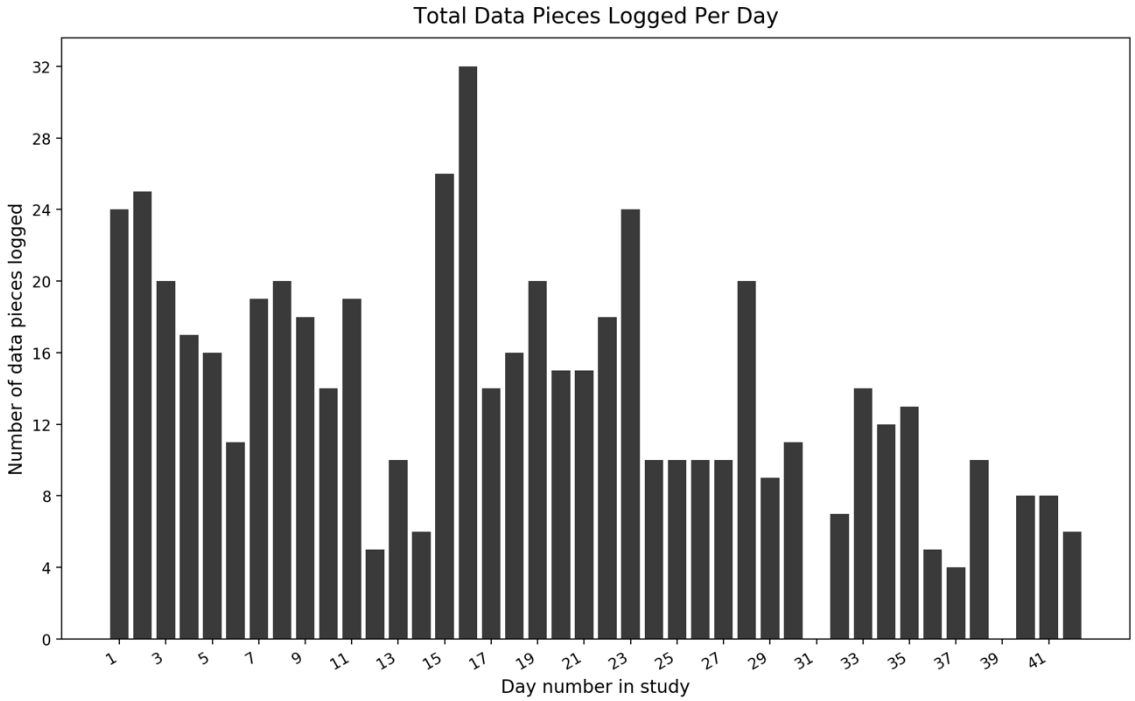


Figure 17. Number of data pieces logged per day, by all participants

Participants exhibited a number of different logging styles and reported a range of different preferences in the interviews and through the experiential sampling survey. The survey data indicates that participants may have logged more often when they were with people they knew (21 responses) or alone (19) than when they were with people they didn't know (6). The surveys also indicate that participants logged much more often when they were at home (35) than when they were out and about (7) and at work (2). Some of the participants logged colours in a balanced way across the day (P8, P11), others showed a different pattern, either logging much more frequently in the afternoon than at other times of the day (P1, P2, P5, P9 and P10) or in the evening (P3, P4, P6, P7).

Each participant's logging behaviour is depicted on a timeline chart, which conveys the app usage data that was recorded directly by the device (see page 135):

- When they logged data (time and day number in the study)
- Which colours they chose
- Which logging methods they used (represented by three different shapes for the data points)
- When they changed their preset colours
- Which topics they set
- On which day in the study changed their topic

An example of one of these charts is featured in (

Figure 18, below), showing the data for P1. All of the timeline charts can be consulted together in appendix VI (*page 259*)

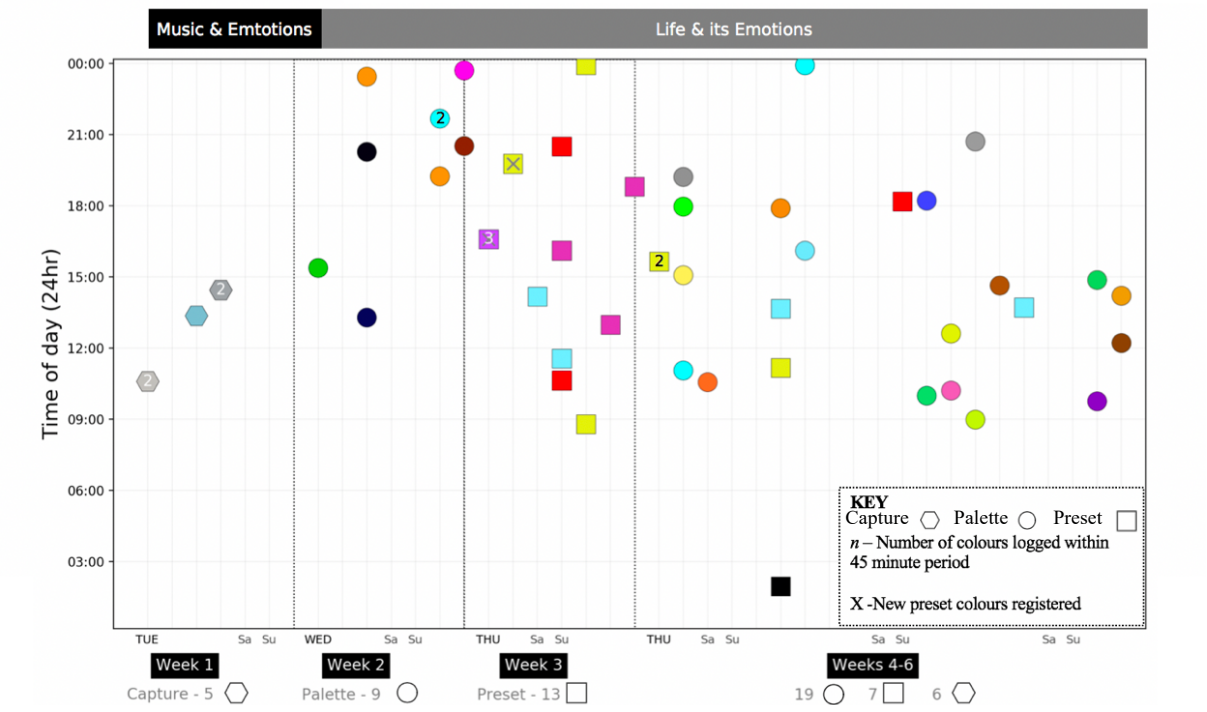


Figure 18. Timeline chart for P1, showing topic, data logs by time and day of the week and logging method.

The full set of timeline charts in the appendix VI can be referred back to as a reference point when reading the findings section that follows. They provide a sense of the logging approach of each participant which can help to distinguish between participants when reading their excerpts from the interviews.

However, the timeline charts also serve as a source of insight in their own right. They provide a sense of the different ways that participants structured their experiential logging. This is a summary of the most marked differences between the logging structures of the participants:

- In general, participants logged a broad range of different colours across the study. However, P8 and P3 had an extreme approach, where they chose from the same limited set of colours throughout.

- Some participants logged within a routine structure; almost always recording a *single* colour on the days when they logged (P3, P6). Others logged in bursts, recording *multiple* colours on the days when they logged (e.g., P1, P8, P9).

- Some participants tended to log more sparingly in the middle of the day. Their logs are focused toward the beginning and/ or end of the day (P3, P6, P4).

- Most of the participants recorded a single colour when they wanted to record an experience. But one participant, P9, logged 4 colours each time (weeks 3-6). Some participants did this occasionally (P7, P10), but not every time.

- Most participants recorded their experiences simply by choosing colours for them, with the exception of one participant - P2, who tried using other features of the app to do so. As mentioned above, she recorded her experiences by pre-setting colours on the *pre-set palette* instead of logging them to her display, in week 3, and often used the topic-setting function to furnish the colour she logged with a text-based description.

When reading the charts, it is important to note that the separate periods of the study (week 1,2,3,4-6) didn't always immediately follow on from each other. Sometimes the starting day was the same each week (e.g., P3). In other cases, there was a gap between the end of one period and the beginning of the next (e.g., P7). This issue arose when participants said they were unable to meet with the lead researcher immediately at the end of a given study period, meaning the meeting had to be delayed until they were available. This is reflected in the chart by differences in the day markers on the x axis - labelled in capitals at the bottom.

Through the experience sampling function participants were posed the survey question, *Why did you choose to log a colour at this exact moment?* There were 46 responses to this question. Out of the possible responses, "*the app caught my attention*", was the most frequently given (31 responses), compared to '*this was when the experience happened'* (9) and '*I waited for a convenient time to use the app'* (6). The interview and survey findings provide a degree of corroboration for each other. "*Seeing the phone display*" broadly fits with "*the app caught my attention*" category of behaviours and "*Having an experience*", broadly fits with "*this was when the experience happened.*"

So far logging behaviour has been broadly represented on the basis of survey and usage data. We now turn our focus to how it has been represented in the interview data. Participants were asked in the interviews why they decided to log colours in the first place. This was about getting a sense of which factors affected the decision to log. The resulting discussions, indicate that there were three main dynamics that prompted users to log colours:

- *Seeing the Four Data-Piece Display*
- *Having an experience*
- *Routine logging*

Logging prompted by seeing the Four Data-Piece Display

In total, participants described 31 instances of logging where the *Four Data-Piece Display* acted as a trigger for their decision to log an experience. These examples account for 10 of the participants (P8 and P6 made the most references - 4 , and P11 the least - 1) and cover all three of the widget types.

A typical response went:

> *"I guess it was seeing the background on my phone…"* (P10, week 3, capture)

Three of the participants (P1, P9 and P8), described the display as being the *most common* prompt for them to log a colour. For example, P9 said:

> "*I think occasionally I would open my phone with the intention of logging, but that was only a couple of times. More often it was seeing my phone.*" (P9, week 6, *all*)

In his week 6 interview, one participant, P8, pointed out that when his decision to log a colour was prompted by his phone display, he tended to log less extreme emotional experiences than in other situations:

> "*when an event triggered my logging, it was usually on the two extremes. It was either feeling at my best or worst. However, when it was something in between, it was more likely that it was when I was just using my phone."* (P8, week 6, all)

This observation is supported by some of the examples of display-prompted logging that other participants also described. In some cases, the terminology used implies that they didn't put much thought into what they were logging when they were prompted by seeing the display:

> *"I think I was already on my phone. I think I was in quite a good mood. And so I thought, I might as well log this. I'm not sure I put too much thought into it."* (P10, week 6, all)

There is also a sense that in some cases participants felt they *ought* to log something, rather than being intrinsically motivated to do so, when they saw their display. This is implied in P10's phrasing, *"I might as well log this"* above, and also in this example below, where P5 says that she "*should probably log something":*

> *"Yeah, so that one time I was in my kitchen boiling the kettle and I thought, oh, I should probably log something. The wall was quite a vibrant green and so I thought I should log that. I think I just had a minute. I was scrolling through Instagram and was just like, looking at my phone."* (*P5, week 2, capture*)

Logging prompted by an experience

There are 89 excerpts from the interview which link the emergence of a specific experience with the decision to log it. These examples cover 10 of the 11 participants (Table 9, below) and each of the different widget types. The exception is P3, who, as the next section further down will show, was the most routine-driven logger.

Participant	Number of examples
P2	14
P7	13
P9	12
P11	9
P1	9
P6	8
P8	8
P5	7
P4	7
P10	2

Table 9: Number of interview excerpts linking an experience with the decision to log it

This is a typical example of an experience-prompted log, as described by P8:

> *Man Utd lost. That was red. I did a shade of red because… hmmm.. where did I get the shade of red from. We were on the move… Hold on… I think we went out for lunch. I don't think I could find a red at that time and perhaps I had to wait and log it later. (*P8, week 2, capture*)*

A notable characteristic of experience-prompted logging is that it appears to have generally arisen when users were experiencing more extreme emotional experiences. P1, P9 and P8 all pointed to this relationship. This forms a contrast with display-prompted logging, which was associated with milder experiences.

P1, said that he would only be prompted to log when experienced a strong emotion:

> "*I normally log intense emotions. So, I think that there have been some times when I don't think about the app, when it's a mild emotion. But there have been times when something has been happening, when I've been like. Woah! This is great! Or times when I've been like, Oh! I want to kill myself! For example, when the code I'm writing just isn't working. And then I realise, oh I've got the app, I'm going to log this*." (P1, week 6, all)

P9, noted that she would only log experiences when something out of the ordinary had happened:

> *"I think kind of, having a strong emotion or feeling, a bit more than an ordinary feeling. Or if a particular event had happened in the day. I remember playing a board game with my family and that was a nice experience. I logged that. It was when things happened rather than nothing."* (P9, week 6, all*)*.

In this second example, P9 is referring to a period of stasis during the Covid-19 lockdown when there wasn't much happening. The lockdown situation brought about a set of abnormal

circumstances, which may have accentuated her tendency to log "*when things happened rather than nothing'*, bringing it into more focus than ordinary life might allow.

It is important to note that there was a certain degree of inference required to determine whether a given scenario-of-use was an instance of experience-prompted logging or prompted by something else. In the "*typical*" example from P8 quoted above it is clear that the experience – Man Utd losing, prompted him to log the colour. There is a direct link drawn between the experience and the decision to log in the order of events he describes. However, this wasn't always the case. Sometimes it was difficult to determine what the root cause of logging was, as these two examples from P2 demonstrate:

> A) *I was doing the colours when we were out. You see, those are the colours I associate with being happy and nice.* (P2, week 2, large palette)
>
> *B) I think I was taking some of the holly leaves. And the colours are really, really close to what you look at. We were at Warton Cragg and it was gorgeous, and I thought; right, I'm gonna take one of these.* (P2, week 1, capture)

The first example is described in an imprecise, general way, making it more difficult to determine the sequence and linkage of events. In the latter example, where the sequence of events is elaborated in more detail, it is clearer that the experience of being on the walk was what prompted P2 to log the colour.

In some cases, the second-person interview technique helped to bring greater clarity to the order of events. This is exemplified by this exchange with P1, below, where he slowly uncovers a memory about a time when he logged a brown colour:

Initially, when P1 first mentioned logging the brown colour, the precise details of how the logging process unfolded weren't clear:

> **P1***: "I think that the brown is this morning. Because I woke up because I wanted to get to work to do some emails and stuff. But I wanted to do some housework as well. I think I got up and I was a bit stressed because I…hmmm…. I got to a moment when I was like. Ah... ok I need to get things sorted… I think that's why I chose the brown…"* (P1 weeks 4-6)

However, after having been asked to think about where he was and what he could see and hear he begins to recall more details about the order of events:

> **Interviewer**: "Ok, so think about where you were. What you could see, what you could hear"
>
> **P1:** "*And so… I start packing stuff from my bathroom…*[*pauses*]*"*

Sensing that P1 is revisiting the memory in his mind, the interviewer switched to non-directive prompting; repeating what P1 has said back to him. The details of the experience and order of events gradually became clearer to P1. He recounts that it was actually the experience of being stressed itself rather than another stimulus that prompted P1 him to log the colour brown:

> **Interviewer**: "*So you start packing everything in your bathroom*."
>
> **P1**: "And so then… hmm… ah the food… the food! You're good at this! I had a lot of vegetables and so, what I've made is vegetable soup with a lot of different vegetables. And so I'm going to have that for lunch and have that for dinner and I'm going to put that all in the freezer [Throughout this period he is looking upwards and away from the interviewer] … Ok so yeah (claps hands), so now I can see the moment. It was coming after the kitchen, right after I had been doing stuff and…"

Interviewer: *So you were in the kitchen, you were doing things, moving them around. What's the thought process?*

P1: "I think it was like escalating levels of stress. I had all these things to do. I went down to the kitchen, there were all these things around. And I was thinking, I have all this stuff to do. And I think I reached a certain point, where I was continuing to do this stuff… And it got to that level of intensity where I was like, OK, I want to log something*."*

Routine logging

Two of the participants, P3 and P6 (week 1 only) said that they tried to set themselves routines, where they would log colours at a particular time of day. They both said that it made sense for them to log at a particular time of day because it fitted their topics. P3 wanted to rate his day, which made sense to do at the end of the day. P6 wanted to rate her sleep, which made sense to do after she had woken up in the morning.

P3 was asked to describe the details of his logging process through the *second-person interview* method questioning. This exchange revealed that there was more to his routine than simply logging at a particular time of day. He actually appears to have integrated experiential logging into his nightly routine activities before going to bed. It is notable that although he is asked to describe an individual logging instance, he instead chooses to describe his general logging process, emphasising how it became a routine for him:

Interviewer: *OK, we're going to wind back to a particular moment when you logged something. So let's wind back to beforehand. What happens first?*

P3: *Well I'm cleaning my teeth, I'd have let the dog out, P4 would be in bed, I'd be sat on the bed facing the door, I'd then go, like right. I need to do this*.

Interviewer: *There's quite a lot going on here. You're cleaning your teeth. What can you see around you? What can you hear?*

P3: *I can hear the toothbrush, it's an electric toothbrush. And I can see the light and see P4 getting ready for bed. I can hear the dog milling about beyond the door.*

Interviewer: *Then what do you do?*

P3: *Then I turn off the light as I go back into the bedroom. I have a glass of water. I get out my phone to check my alarm for the next day and to see if I have any messages to respond to for the next day. And then I would sit on the side of the bed, facing back out toward the door. I would then open up the app. And I would kind of, not in depth – wouldn't sit there for 5-10 minute, but I'd try to do a sort of quick sum up of if something notable happened that would influence my rating. Some days it would be that nothing particularly special happened. It was a pretty routine day at work. And then other days, it would be like oh! There was that… I had some disagreement with somebody in a meeting. Or there was some sort of frustration with some piece of work that really annoyed me for a period of time. But then I played football that night maybe and had a really good time at football. Or, I dunno, I had a nice dinner or something like that. And I'd go, well, on the whole that irritating part of the day does not outweigh the other things that were more positive that happened. I'd go, ok, it's that colour and I'd close my phone, turn the light off and go to bed*.

Interviewer: *What are you thinking as you… So you sum it up, you think about what the colour means… Is there anything that goes through your mind after you've logged it?*

P3*: I guess that if it is a good day, you feel quite positive about it. And I guess what I said before, my mindset would usually be to find the negatives. And if you've steered away from what is my natural way of thinking and gone… no no.. It wasn't all that bad… just because of that thing… And yeah, I think you get a kind of positive feeling,*

because you know… yeah, you are doing something productive here and you're looking at it in a better way and that's a good thing. That can only help.

P6 can also be classed as a routine-logger. However, she acknowledged that although she planned to log her sleep quality in a routine way, she was often not disciplined enough to do so:

> *"It was only when I remembered to do it. Then, I'd think. Oh, how was my sleep last night. I didn't like to wake up and do it. I don't know why, because it is like, right there, but I just didn't."* (P6, week 1, pre-set palette)

This underlines the challenge of maintaining a routine logging structure. Sometimes participants just simply forgot to log. However, there were situations when the phone display helped them to remember. Both P3 and P6 gave such examples:

> "*A couple of times I did completely forget about it. So it was only when I remembered to do it. Then, I'd think. Oh, how was my sleep last night. I didn't like wake up and do it. I don't know why, because it is like, right… It was when I remembered about it. Sometimes it was like, "oh god", it's staring me right in the face, I should do it. And then I did log it."* (P6, week 1, pre-set palette)

> *"There were some occasions when it'd catch my eye and then I'd be like, oh! I didn't do that yesterday and so I'd be doing it the following morning, to record the previous day."* (P3, week 6, pre-set palette)

It should be noted that unlike the other two prompts (display-prompted, pg. 150, and experience-prompted, pg. 151), there is no indication that routine logging involved mainly mild or strong experiences. Whether or not participants decided to log at the given time-of day appears to have been independent of the extremity of the experience.

5.3.2 Reflection

In the interviews, participants spoke about how they engaged with the meaning of their experiences through their use of the device. As discussed in chapter 4, there is substantial debate about what constitutes reflective thinking, in particular how deeply an individual must engage with the meaning of their experiences for the process to be defined as reflective thinking. Some argue that, in addition to considering the meaning of something, the individual must exhibit a fundamental shift in perspectives or beliefs. Others vouch for a more subtle conceptualisation of reflection.

To encompass the full spectrum of evidence of reflection from the user study, this section begins by laying out findings associated with *topic-setting*. How participants set and changed topics over time, and why they changed them is indicative of how they wanted to engage with meaning through the use of the device in the first place. The next section after this, covers instances when users *considered the meaning of their experiences.* The final section covers instances when consideration of the meaning of experiences resulted in a *shift in perspectives.*

Topic-setting

Participants were able to set a topic with the topic setting feature of the app (see page 124, design decisions) and were free to change it whenever they wanted. How and why they changed their topics over time provides an insight into how they wanted to express themselves through the app, and as such, which aspects of their life they engaged with.

Most participants perceived the topic as a fixed overall theme for their logging. They set their topic and then logged colours associated with it. This meant they rarely changed their topic. For example, when P4 set her topic to "*Rides on Pippin*" for a week (week 3), all the colours she subsequently logged were associated with this overall theme. Most topic changes were also made early on in the study. There are only two participants who changed their topic after week

3 and no changes from week 5 onwards. This indicates that there was a probing period early on, where participants were working out what they wanted to focus on, but once they had settled on a topic, they didn't want to move onto something new; at least they didn't want to do so within the time-limits of the study.

P2 is an outlier, in that she changed her topic much more frequently than the other participants. While all the other participants used it as a broad theme-setter for the group of experiences they were logging, she used it to describe features of the individual experiences she logged. For example, in week 2 when she logged a purple colour and simultaneously switched her topic to 'Frosty Night' to describe what the colour represented (*see appendix VI, p. 259*).

On the basis that they generally changed their topic infrequently, it could be argued that the participants used the app in a fairly rigid way. However, when examining how they logged their experiences within the confines of their topic and the types of topics that they chose, it suggests that they used it flexibly. It appears that the topics that participants set didn't always precisely reflect the topic they had registered on the app. For example, P9, P7 and P10 all said that their topic only loosely represented what they logged.

> *"So I set it as social interactions. but I found that as time went on, I was logging the feeling about those interactions."* (P9, week 1, capture)

Second, participants who started out with topics that had a rigid, functional, task-focus, tended to move toward topics with a broader subjective-experience-focus (*Figure 19*, below) emphasising emotional aspects, as the study progressed.

Participant	Task-focused
P3	Work Tasks
P6	Sleep
P9	Social interactions
P11	App usage/weather/ webpage loading times

Subjective-experience focused
Rating my day
Mood
Feelings
Things that make me smile

Figure 19. Transitions from task-focused to subjective- experience-focused topics

P3 wrote the following on the experience sampling interface in week 1, explaining his own transition to a subjective-experience focus:

> "*Early stages, but felt rating work tasks was a bit limited and perhaps focusing on the wrong thing. I'm now having a go and giving a subjective review of how my day has gone, across everything. I feel I often have a tendency to be quite negative, and this could be a way to look across all aspects of the day, and focus on the good things more than I do currently, will see how it goes!"* (P3, *experience sampling*, day 2)

Participants also evidenced a shift from narrow, specific topics to more general topics (Figure 20, below). The one participant, P8, who started out with a very general topic at the beginning ("Life in general") kept this for the whole study.

Participant	More Specific Topic
P1	Music and its emotions
P3	Work Tasks
P5	Mindfulness
P7	Parenting

More General Topic
Life and its emotions
Rating my day
Emotions
General feelings

Figure 20. Transitions from specific to more general topics

Although participants shifted from more specific, task-related topics to more general, subjective experience-focused topics, this didn't always mean their actual logging necessarily

always followed suit. P1 gave an example where, despite having *set life and its emotions* as his topic, he found himself reflecting on the task of coding an app:

> *I can think of at least one occasion when I tried one method (for solving a coding problem) and it worked and I logged a bright colour and I continued working. Some stuff didn't work. And then, when I fixed that, I saw the bright colour there between all the dark colours. And I thought, ah! That was the method I tried before that worked… and I went back to that.* (P1, week 6, all)

As they probed around with different topics in the first weeks of the study, participants appear to have been trying to find something that felt meaningful for them on a personal level. In interviews, P11, P4 and P2 all spoke about this. For example, in weeks 1 and 2, P11 was struggling to find a purpose for the app and it was only in week 3, once he set the topic to *"things that make me smile*" that he really settled:

> *"I think if you'd asked me that a few weeks ago, one of the things I might have asked for would be recommendations of questions that other people have used. But I actually think that would've been more restrictive for me. Because the early ones I did didn't work for me. I needed to explore for a while to find a solution that worked for myself. And it was quite a reflective, personal experience*." (P11 week *3*, capture)

Some participants also reported that external conditions had an effect on their topic choices. P2, who was logging experiences from her walks and P11 who was logging the weather, both noted that the weather affected how engaging their topic became, as the season moved into winter:

> *"I think I've only logged something the once in the last however many days. … I was struggling a bit for an idea… Because obviously it's just cold and wet at the moment obviously…. So following the weather is just cold, wet grey all the time."* (P11, week 6, all)

P10, meanwhile, mentioned that moving to a different country, Japan (in week 4) made him focus on his experiences of places rather than music (which he had been logging in weeks 1-3).

> "*I think it might actually be because I've been outside a bit more I'm in an environment, not that which I'm not used to, but one than where I'm not often present. I suppose maybe I wanted to capture the difference between the locations. I actually found that the link to my topic, music, was actually far less. For example, in week 1 it was linked to the music. But now it's kind of, when I saw a nice colour that I liked, I'd take it, and the link to music wasn't as much.* (P10, week 6, Capture)

Considering the meaning of experiences

There are two main occasions during the interaction lifecycle when users appear to have considered the meaning of their experiences while logging colour data and while revisiting previously logged colour data on the *Four Data-Piece Display.* The findings in each case are set out in the first two part of this next section (*Considering meaning while logging colour data* and *Considering meaning while revisiting colour data)*. There is also a third section (*Considering meaning beyond interaction)* which sets one exceptional example of a participant having considered the meaning of their data when they weren't logging or revisiting it.

Considering meaning while logging colour data

Participants described a large number of examples of situations where they considered meaning of experiences while logging them. In total there are 75 excerpts from the interviews like this, which came from 10 of the participants (Given that this is a large data set, all these excerpts are provide in appendix V (pg. 252)

Participant	Number of examples
P2	14
P10	11
P1	10
P9	7
P11	6
P7	6
P6	5
P8	5
P5	4
P4	4
P3	3

Table 10: Interview excerpts in which participants described instances when they logged data and associated it with a meaning

Sometimes users would choose a data piece that summarised a group of experiences, for example when P6 said she logged a white colour to characterise an activity she had been doing over the course of the day:

> "*Last week I did loads of paperwork. I was sorting out finances and stuff. And I was surrounded by paper. I picked white because it was the colour of paper. But honestly, I was just looking at it and I was like, what should I pick and I was like, this colour represents my day, because I was surrounded by paper all day.*" (P6, all)

At other times they logged colours that represented a single ongoing experience that was currently unfolding. For example, when P2 logged the colour of the fire representing her enjoyment of the "lovely" experience:

> *"Last night it was cold and freezing and I was sat by the fire and I would just do all the fire colours... yellows, reds and oranges. It was lovely. Because it was freezing outside*

last night. It was minus something. They were all cosy, warm colours, I thought." (P2, week 6, all)

After describing examples in the interviews, participants sometimes spoke about the general affect that the occasions of experiential engagement had on them. One participant (P6) spoke about how using the app made her think more *deeply* about an experience than she would otherwise.

"I probably wouldn't have stopped and thought as deeply about having had a relaxed day if I hadn't had to pick a colour." (P6, week 3, large palette)

P11 and P1 said that logging colours generally made them more aware of their experiences. P11 highlighted how it brought his attention to the small pleasures in life.

"I did definitely think more about the simple pleasures in life and genuinely trying to focus on the positive experiences. Because I think I do have a tendency to overlook them…. to be able to think back to them after a day or two and be reflective was good." (P11, week 6, all)

P1 said that it made his emotions more tangible:

"I don't know if it is a conscious response. But maybe, the app is helping me to be more aware of my emotions. Not in the sense that I am not aware of them. But aware in the sense that I have to label them. So maybe, I am used to thinking about my emotions in a way in which I couldn't give them words or label them. And now with this app, I force myself to do it." (P1, week 6, all)

Other participants (P4, P7) said that logging colours made them think about their experiences more *frequently* than they would otherwise. P4, for instance, said:

"I think I go through phases, where I evaluate sessions more so than others. When I'm struggling with things, I am more likely to evaluate things. I think it was quite good to

have it. To make me do it! So it varies on how things are going with her and what's going on." (P4, week 3, pre-set palette)

Considering meaning while revisiting colour data

Participants also described some examples of having considered the meaning of their experiences while revisiting data. There were four examples in which participants (P4, P11, P2, P10) described having considered the specific meanings of individual pieces of data. Each of these was an instance when they were using the capture logging method:

"It was nice because it made me think of pippin (her horse). So that was nice." (P4, week 1, capture)

I could look back and say ok, well that was the dog that I was coming back to… Or, the orange shade of ermm… a bottle of Christmas iron bru that we sell… It's called Crimbo juice (P11, week 3, capture).

In other cases, participants (P11, P8) spoke about the display more generally:

e.g., "*So if you just look at this. (Points at phone wallpaper), it's a very quick way of seeing how your life's been over the last few days.*" (P8, week 6)

P1, whose topic was *Life and its emotions,* remarked that he often couldn't recall the individual meanings of his colours easily and so he tended to consider the general picture of how life was going. He could only do so, when an individual colour stood out. As such he considered them as providing a general emotional landscape.

"If they were all the same, I would just say, ok, this has been the general, my general emotional landscape for the last few recordings… If there was a huge difference from one colour compared to the other three I could recall what they meant. I could say, ok this was when this happened." (P1, week 6, all)

Another notable characteristic of displayed data is that the data could have negative connotations for users when they were considering its meaning. There were two participants who described such examples:

> *"If I'd had a bad social experience with someone and I'd used a black colour, that colour would remind me of the conversation. I didn't like that."* (P9, week 1, capture)

> "*For me, when I was recording things that weren't positive, it was more difficult to use the app because I was… It was a self-fulfilling prophecy. You're feeling gloomy, you record gloomy and then you look at your phone where you see that you recorded gloomy colours, it makes you feel more gloomy."* (P11, week 6, all)

Considering meaning beyond interaction

All the examples above are occasions when users engaged with meaning while using the device directly; either logging a colour or looking at their colour display. P1, however suggested that he sometimes considered the meaning of his experiences and associated them with colours without having physically used the device. He explained that this was a product of him having grown used to translating his emotions into colours:

> *"At the very beginning, when I started a few weeks ago when I started the experiment. I wasn't sure how I felt about the translation of the emotion in my mind. Is it that I am feeling the emotion in a different way or is it that I am expressing it in a different way? But now, having been a participant in the experiment, if I feel an intense emotion, most of the time, I can think of a colour because I have the app. And it isn't that I have the app and then I think about the emotion and the colour… It's that I feel the emotion and then I think, if I were to record this, I would choose this colour. So if I have the time to record it, I would record it. But if I don't have the time, I would not record it, but I have already thought about that process of translating the colour into the emotion."* (P1, week 6)

Shifts in perspective

The passages cited in the previous section, represent instances when the device enhanced or enriched a users' knowledge in a subtle way rather than changed their perspectives. It brought their attention to elements of their everyday life, making them more aware of the qualities of their experiences or increasing the frequency with which they focused on them.

This next section covers instances that provide evidence that using the device affected perspectives or beliefs. In this case users were not only considering the meaning of their experiences but seem to have been evaluating their deeper implications, leading to a shift in perspective. In some cases, this affected the way they felt about the situation or incited them to take action and change their behaviour.

This appears to have been something that happened occasionally rather than every time a participant engaged with an experience. The survey responses provide a general gauge for this. Out of 52 responses to the experience sampling survey question, "*You just logged a colour*, *did the app make you question the way you think about something?",* 10 of the responses were "*yes",* 34 were "*no"* and 8 were "*I'm not sure*". There are also a number of interview passages that provide an insight into how this manifested itself.

Most of these instances can be separated into two categories: a) a change arising from looking at the display on the phone and b) a change arising from logging a colour.

Affecting perspectives while users are logging data

P2 and P11, both described examples of occasions when logging a colour by capturing it with the capture logging method made them evaluate the qualities of a current ongoing experience, which resulted in them formulating a perspective on it. P2 formulated a perspective on the beauty and impermanence of nature when logging a colour. The act of logging the data seems to have prompted her to consider the deeper meaning of the elements of the experience:

> *"I logged lots of colours. And those colours are a tree, a plant and the sky… And I thought that was really good… Because it was just beautiful and it made me happy. And I thought, we're not gonna see many more of these this year… This colour blue…. It made me think about how lucky we are to be here and to just wander about this gorgeous countryside on such a lovely day."* (P2, week 1, capture)

For P11, meanwhile, the process of logging a colour became stimulus for him to shift his current focus toward the positives of the current moment. At first he felt that the situation was "*gloomy*" and "*grim*". However, having considered the qualities of the moment when logging a colour he started to focus on the positives and think of the situation as "*warm and comfortable*."

> *"There was a really vibrant orange colour that I recorded once and that was a train ticket. It was really close to Christmas, it was a really, really long week; I'd been working hours and hours and hours. I'd just done like a 12-hour shift and it was pitch black dark. There was no light, and it was really gloomy and everything was sort of grim. But being sat on the train was such a warm and comfortable feeling. And I recorded the colour of the ticket and that put me in a totally different frame of mind, Because I was reflecting on it short term, I'm on my way home I am currently warm and comfortable. And I had found a warm and vibrant colour in the gloom as well. You know, it was a bright orange colour of the train ticket."* (P11, week 6, capture)

Another, slightly different example comes from P3. Rather than changing his perspective on a single experience that he was having in-the-moment, as was the case with the two examples above, he changed his perspective on the series of experiences he had had across a day when logging a colour.

He said that at the end of the day, he would routinely choose a colour that represented his day as a whole. The process of picking the colour would result in him developing a more positive perspective on the day that previous:

> *"I think I have a tendency to fixate on certain things. But actually, when I look at the day as a whole I can see that, this bad thing might have happened, but the day was still pretty good for all these other reasons. In terms of selecting a colour to represent it, I was basically picking different shades of green. I think I basically concluded that most of the time the day is pretty good. It seems to be rare that I have a genuinely all-around bad day.* (P3, week 1, large palette)

In the final interview, he considered the broader impact that this process of summing up his days with a piece of colour data had on his life. He said that it had given rise to a general shift in the way he perceived everyday life, affecting his behaviour:

> *"I think that coming home at the end of the day and chatting to my fiancé about how the day has been. There would often be a tendency to go straight for the really bad thing and just go straight to talking about that. But I do think that even if I've not always been logging it, now I'd maybe have that conversation differently. And I'd say, oh no, it was pretty good. Just these things few things happened that were a bit annoying. Because I do think that it has changed my mindset to an extent, in trying to find the positive instead of going straight to[the] really bad thing that happened.*" (P3, week 6, all)

However, he also acknowledged that after having had this shift in perspective, the device became less useful to him as his logging became repetitive:

> *"As it's gone on, I've basically been repeating the same thing. I think that when I've been repeating the same thing, that's probably when I've drifted away from using it. I'm like, what new thing is this adding? What am I learning if I'm basically saying that every day is a pale green day."* (P3, week 6, all)

Affecting perspectives while users are revisiting displayed data

Four participants (P11, P1, P6, P8|) spoke about the effects that displayed data could have on their perspectives. One participant, P11, spoke about this generally, saying that he would look at the colours on his display, representing *things that make me smile,* which changed his perspective on how his day had been, giving him a more positive outlook on the day:

> "*By recording positive experiences, it put me more… It made me more mindful of that positive experience as and when it was happening. And it allowed me to… whenever I opened my phone, I would see those 4 colours and it would put me in, or make me aware of those positive experiences. You know… even just reflecting on positive experiences puts me in a positive mood.*" (P11, week 6, all)

Other participants gave more specific examples, explaining how they would analyse relationships between the individual pieces of data on their display. P6 examined the relationships between the sleep data on her display, linking the pattern in the sleep data to her own perceptions about her work-life. She said that when she saw her display she reflected on how the colours might be different if she wasn't on holiday from work:

> *"I'd done quite a lot of blue - that was my good sleep - then I realized that if I wasn't on half-term holiday (school holiday) I probably wouldn't have done so many blues. That*

was probably the main thing. I did put blue maybe two days in a row or three days in a row and then I was like, I bet I wouldn't have done that if I was back at work." (P6, week 1, pre-set palette).

There are also examples where, having drawn an insight from the relationships between their data, participants decided to take action and change their behaviour:

*"Mostly when it was all dark. I thought, OK, maybe I need to do something… I was thinking, what should I do to change to a brighter palette of colours?" (*P1, week 6, all*)*

"*I had a similar experience this week as last week. I could see the background of my phone and see that it was all red and I thought, ooh my God!… It did instigate me to think, ok, come on! Try to do something positive*." (P8, weeks 4-6, all).

In both cases, seeing the negative connotations of a series of colours on their display seems to have incited the participant to think about doing something positive and uplifting.

However, seeing colours with negative connotations didn't always lead to a positive outcome. After seeing the repetitiveness of his website-use mirrored back to him (topic – which websites/ apps am I using), P11 decided to change his logging approach and focus on a different topic. He didn't want to use the app for engaging with experiences that had negative connotations:

"I remember looking at it on the second day. I had a very similar black colour, very similar dark blue colour, very similar red colour and I was just like… ooooofff.. I don't want to be reminded of this…. I've just looked at the same websites again! So that's why I thought, I'm gonna need to change this. I'm gonna need something more positive and more useful for me. There's no point in me recording the same colours… the same repetition over and over again." (P11, week 1, large palette)

5.3.3 Design characteristics

This next section describes themes relating to the design characteristics of the app and how they appear to have affected user experience. It begins with an overview of how the participants employed colour to represent their experiences and their perspectives on its attributes as a data form. It then sets out participants' perspectives on the different logging methods – *pre-set palette*, *large palette* and *capture* – and how these affected the way they associated meaning with the colours they logged. It then covers how they did this in different ways through the various modes of logging. The final section sets out participants' perspectives on the two historical data displays.

Colour

When users were logging colours, they had to make decisions about which colour to choose to represent a given experience. As the logging timeline charts in the appendix VI (p. 259) illustrate, the participants logged a large range of different colours with the app, with some participants using a much more diverse set of colours than others. P8 and P3, most notably, used a more constrained set of colours than the others, with the latter only ever selecting a small set of different shades of green and red throughout the study. This reflects the overall more-structured way in which these participants used the app. On appearances, the colour choices of the other participants in the study look fairly random. However, the interviews revealed that most of the time there was a broad pattern in how participants selected their colours and associated meanings with them.

One such pattern in colour choice, is that several the participants said they chose colours, and associated meanings with them, based on their brightness or hue. Eight of the participants said that there was a relationship between the brightness of the colours they chose and the level of positivity of the experience they represented. For example, P7 said:

> "*Cosy, I think… hmmm…I think dark colours when I wasn't good. Like browns or greys… I think more blue colours, brighter colours when I was happier.*" (P7, week 6, large palette)

P9 and P7, meanwhile, both said that they used black or white to represent the *absence* of feeling:

> *"...there were times when I did just choose white and black. They were just when I was not feeling anything (*P9, week 6, all)

Five of the participants said they differentiated the meaning of colours by their hue. P3, P6 and P4, for example, all related their colour choices to a traffic light system – Red, amber, green, ranging from a bad experience to a good one.

> *"Red was if I felt overall negative about the day. It was a bit like traffic lights. Yellow was if it has been alright and green was good"* (P6, week 6, all)

P8, meanwhile, created his own unique meaning system, where each hue fitted onto a spectrum ranging from good to bad experiences:

> "*I had these 5 colours. Red, purple, yellow, green and blue, in a sequence. So red means, let's say… it's something like a Likert scale… so red could be 1 or 0, blue is the maximum. For example, a few days ago, I was watching a football match; we won – so, things like that. And so, things that made me angry, or frustrated or sad, would put the red one. Or other things I would put the purple, yellow green.*" (P8, week 1, pre-set palette)

As touched on above, P3 and P8 employed colour consistently across the study as a whole. Others did so for periods of the study. But P1, P2, P7, P9 and P11, chose colours in a more liberal fashion throughout. Although the association of meaning to between different levels of brightness and hue were a factor when this second group of participants were selecting colours, they appear to have only influenced choices loosely. These participants generally

selected from a much larger range of hues and brightness levels and other factors such as context and intuition seem to have influenced their choices.

P1 used colour slightly more flexibly than P3 and P8. At times he picked colours systematically, selecting from six different with fixed meanings. However, he also had another three colours in his system which he applied more liberally, depending on the context in which he was experiencing a given emotion. He explained that sometimes he would apply different colours to the same meaning, depending on what felt right in the moment. His decision seems to have been shaped by the nuances of the context. But then also what felt right in the moment:

> *"I would say that my dark colours would always be black and grey. And then, I've used some dark blue. The brightest colours they were red, yellow, bright blue. So those are the main six colours. But then I've also used some kind of brown, purple. I used pink once. So I've used 6, mainly these colours, and then another three when I wasn't sure about… There might be some occasions when you might have two different options. Either a colour could be representative of several different emotions. Or the other way around, an emotion could be represented by two or three colours, which are gonna be pretty similar. So, it is not that an emotion is always the same. It may have different degrees and it is affected by the context where it is happening. So this all changes it. It's not going to turn from dark blue to pink. So it's not going to change from dark blue to pink! But it could be from dark blue, to grey, or purple."* (P1, week 6, all)

P1's logging style can be considered as a hybrid approach. He logged in a systematic fashion at times, like P2 and P8, but also he gave himself some license for greater flexibility. Others chose colours more liberally still, without aligning colour choices with their previous ones at all. P9, P7 and P2 all emphasised how their intuition played a role in their colour choices. They would pick a colour, in the moment, that reflected how they felt without sticking to a particular system. From day-to-day their choices could change, as P9 underlines in this passage, when talking about a day when she chose bright, highlighter-pen style colours

> *"Really it's how I'm feeling. So the bright colours I chose, were bright luminous colours. But then again, it was how they went together as well. One day I chose lots of, like, highlighter colours, and that was for a day that was sort of out of the mundane."* (P9, week 6, all).

P7 meanwhile emphasises how the nuances of the context of the moment shaped her colour choices:

> *"It's the beginning of the weekend, I'm feeling nice… I'm sat here now. Maybe I would capture the yellow of that throw. But then next weekend I might be feeling similar, but I wouldn't have that yellow. And it might be that yellow doesn't feel right that day. You have a range of colours and they all have different tones. So you've got more options."* (P7, week 6, all)

The link between context and colour choice appears to have been particularly profound when participants were using the capture logging method. P11, P10 and P2 all suggested that they would choose colours that were a key feature of their environment because they reflected the feeling of the moment. P10 and P2 gave examples when they captured the beautiful colours of the sky.

> "*When I find something that I really like. So this bright orange light just fills our room. And I think it's really pretty, and I want to take a picture of it and remember it somehow. And I've got this handy little app, which I can use to take its colour. There are few examples like that. There's the sunset, the sea as well. They're just things that I like to look at. And I just end up getting the colours for them.*" (P10, week 6, all)

> *"It was just beautiful, and it made me happy. And I thought, we're not gonna see many more of these this year, this colour blue.'* (P2, week 1, capture)

For P11, meanwhile, it was the vibrancy of a colour on an object that shaped his colour choice:

> "*...if there is a particularly vibrant colour that catches my eye within a piece of packaging. Or in the immediate vicinity. I would make a particular effort to record that colour.*" (P11, week 6, all)

In a number of the examples above, the participant mentions that their display also influenced their colour choices. They explained that they were trying to find colours that blended well, aesthetically with the colours they had already chosen. In total nine of the participants said that aesthetic appeal had an influence on their colour choices at some point in the interviews, the two exceptions being P3 and P8. In some cases, for sustained periods of the study, aesthetics appears to have been the only factor governing colour choice (P4 - weeks 1-2, P6 – weeks 2-6, P5 – throughout). One participant, P5, said that she found it challenging to assign meanings to colours altogether and so focused only on aesthetic appeal:

> *"I think I chose these colours because they would look good on my background.... That was my main thing, was choosing colours I liked. And then I was thinking that I would add a meaning to them after. But I never really got to that adding a meaning bit"* (P5 week 6, all)

But generally, aesthetic appeal appears to have been a minor, rather than the primary ingredient that went into the colour choice decision. For example, P1 said that he would think about the meaning of the colour first. But then if, having done this, he was left with more than one option, he would opt for the one that went most harmoniously with other colours on his display:

> "*I logged two colours several times, or three, that were pretty similar, and it was kind of strange. It was 4 rectangles overall, with three of them that were pretty similar. So maybe the symmetry was broken. And I'm like, ok, I don't like that. So I was sure that I was logging my own emotion, but I was telling myself, ok, well it's my own decision*

about the colours. It could either be this colour, or this other colour. So if I can use one of those and A matches my screen better, I'm gonna go with A." (P1, week 6, all)

Two participants, P3 and P4, also mentioned that they sometime felt an urge to pick a particular colour, not because it looked aesthetically pleasing, but because it had more positive connotations. P3 described it like this:

"*If it was just a kind of an alright kind of day and nothing particularly happened either way. So I would say, I wouldn't go to a yellow…Maybe… maybe for those days a yellow would've been more representative. But I found myself maybe on some level wanting to put the light green…. Wanting it to say that every day was green."* (P3, week 1, large palette)

Opinions on Logging methods

In the first half of the user study, participants were given access to each logging method (pre-set palette, large palette, capture) in turn, in successive weeks. Then, in the final 3 weeks they had access to all of the logging method at once. Usage data, showing how often they utilised each of the different logging methods in the final three weeks of the study, provides an insight into their logging method preferences. As the chart (*Figure 21*, next page) shows, participants generally had one logging method that they employed more frequently than the others, indicating a preference for this method. There was only one participant, P10 who used the different logging methods with similar frequency. There is some evidence to suggest that the order in which participants received the different logging methods might have had some influence on their preferences. Four of the participants appear to have preferred the version they received first, five participants appear to have preferred the version they received second, and just one participant had a preference for the version they received last (one participant P10, said he had no preference and used the version in a balanced way in weeks 4-6, so his

preference cannot be established). This implies a bias towards the versions of the app received in the first two weeks of the study.

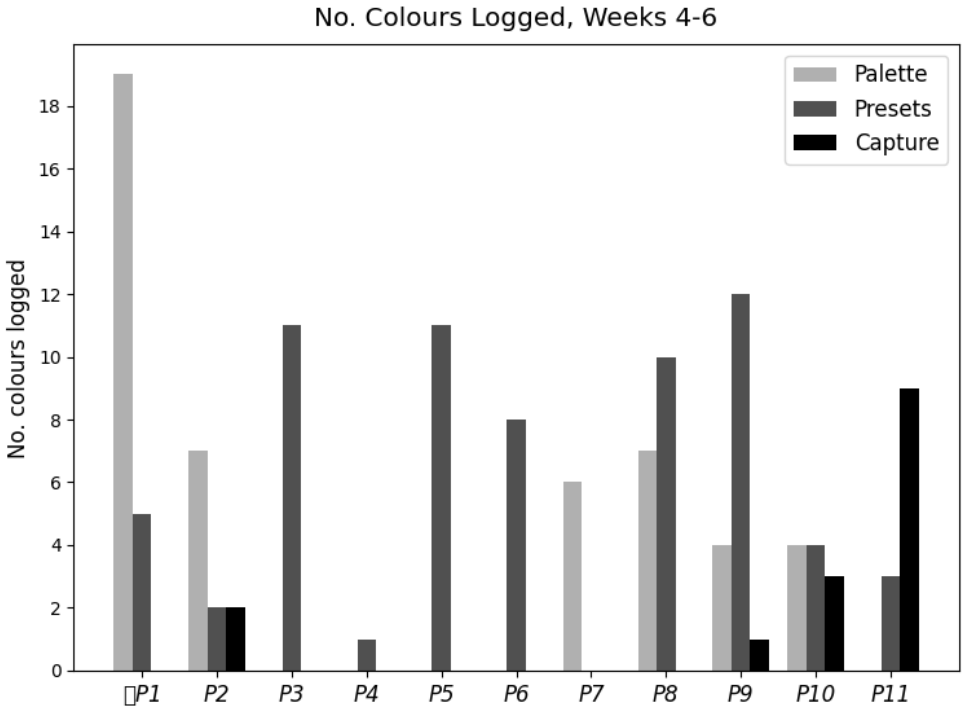


Figure 21: Number colours logged, by logging method, in weeks 4-6

The participants evidently had diverse preferences. There wasn't a single mode of logging that was significantly favoured more than another across the participant group as whole. Based on the frequency of use, each of the logging methods appears to have been favoured by at least one participant. The diversity of participants' preferences is further evidenced by how the participants responded to questions about their preferences in the interviews. When asked to explain why they chose to use a given logging method more frequently in weeks 4-6, participants typically said that they thought it was the simplest to use. Given that they were referring to different logging methods as being *the simplest*, they evidently had different perceptions of what simplicity meant.

Four of the participants (P8, P1, P3 and P6) said that they liked the simplicity of the pre-set palette because they could choose colours quickly:

> *"I've tended to use the one where there's the five pre-set choices, because when you open it, it's the most straightforward one to select."* (P3, week 6, all)

Two of these (P6 and P3), emphasised this point further, stating that the large palette gave them too much choice, hence over-complicating the process:

> *"So, I think overall, that when there is more choice, it is more difficult to interact with. So, I found myself not knowing which colour to pick. So, some days I would just pick any random colour. Because I just struggled to associate the colours."* (P6, week 2, large palette)

For other participants, however, the small range of colours provided by the pre-set palette was a limitation. P7 and P11 both said that being able to just select from colours with the pre-set palette inhibited their ability to express themselves. For instance, P11 went as far as to suggest that such a limited set of options made it depressing to use the app:

> *"It's just really limiting, trying to boil a day down into just these colours. Which might have the opposite effect to what I want… Like in previous weeks where I was just spending loads and loads of time on social media and websites and things that I didn't particularly want to be doing. I found that if I just condense all the things that make me smile into just five colours and 5 types of experience that might be very depressing*!" (P11, week 6, all)

For P7 and P11 the simplest logging method, was therefore the one that allowed them to express themselves openly as well as easily. However, they had different perceptions on which of the other logging methods fulfilled these criteria the best. For P11, the capture widget was the best:

"I found that that process with the capture widget was easier, because I've gone through the process of taking out the camera and looking at it, and maybe clicking a couple of times to find the exact shade that I'm after." (P11, week 6, all)

But for P7, the large palette was the best option:

"*I found the picker the easiest one... The colours are there, and you just pick one."* (P7, week 4, all)

Participants also spoke about how the different logging methods made them engage with their experiences differently. Two of the participants, P9 and P3 spoke about how choosing colours with the large palette app made them analyse what their experiences meant more deeply than when they used the Pre-set palette or capture widgets. P9, compared the large palette she used in week 2 with the capture widget she had used the previous week, noting that logging with the former meant the colour 'stuck' in her mind:

"Yeah, I picked a blue because I was singing at church because that was the colour of the cassocks. And I liked that I could find that exact blue. So, I think that was useful. But then again, I would have been able to do that easily with the last version. But then because I was having more… I was actually having to find it and do it… and almost make the colour, it stuck in my mind more than if you just log It in an instant and that's it, maybe." (P9, week 2, large palette)

P3, meanwhile, compared the large palette and pre-set palette, noting that he was forced to think more carefully about the meaning of the colour when he used the former:

"I used the first one at the start where you had more scope to pick the shade [large palette widget]. Within my head, I think I was maybe thinking about it a bit more and trying to compare days." (P3, weeks 4-6)

On the contrary, participants sometimes picked colours impulsively without having considered their choice much at all. Two of the participants mentioned that they would tend to log with

the pre-set palette when they were in a more extreme situation, when they didn't feel like making a considered, rational choice. This is apparent in this example from P1, below, when he fixed a coding problem:

> *"I told you that I prefer logging with the picker large palette. But I chose this one on Friday, probably because it was faster. So, I knew the colour and probably I was too excited at that time and I was like ok. I will just pick this one here."* (P1, week 6, all)

And in this other example, here, from P2 when she felt sick:

> *"You see yellow is quite a nice colour…. But at the time it just made me feel about being sick… Because I was feeling rubbish and there were just a few that were there [points at the pre-set colours on the widget] I just thought that will do… Because I couldn't be bothered."* (P2, week 6, all)

It was noted in the previous section, on the use of *colour*, that some of the participants picked colours and associated meanings with them in a more structured way than others. Expanding on this, it appears that their preferred logging method was linked to these decisions. P3 and P8, who employed rigid colour systems throughout the study also have in common that they both had a preference for the pre-set palette– they also used this one the most frequently in weeks 4-6. They both explained that they liked the pre-set palette because it let them choose colours more consistently than the others by constraining their options:

> "*There was so much choice it was hard to categorise. So that's why, I think I ended up drifting to that one that was the pre-set choices… Even if I did end up picking the same one most of the time. But there was a clear distinction between my choices."* (P3, week 6, large palette)

In contrast, five of the six participants who picked colours and applied meanings to them more flexibly throughout the study (P7, P11, P1, P2, P10) appear to have preferred the large palette or capture logging methods; themselves using these logging methods more frequently in weeks 4-6.

The exception is P9. At first glance, this indicates that she is an outlier. But upon further examination it appears that the way she used the pre-set palette method had more in common with the way the other participants used the large palette and capture methods than with the rigid way P3 and P8 used the pre-set palette method. This is because P9, like the other flexible loggers (P2, P7 and P10), she adapted the large palette logging method, so it supported her fashion of colour selection. Rather than always select one of the 5 colours they had already pre-set on the widget, as P3 and P8 did, these participants created a whole new set of pre-set colours each time they wanted to log an experience, and then picked one of these. This approach is reflected by P2, P7, P10 and P9 having changed their pre-set colours more frequently across the study than the other participants; with P9 having done so the most frequently of all (Table 11, next page).

Participant	Number of pre-set colour changes
P9	14
P2	6
P10	5
P7	4
P1	3
P8	2
P6	2
P4	2
P3	1
P5	1
P11[5]	0

Table 11. Number of times pre-set colours changed during pre-set palette week (week 1,2 or 3).

In effect, rather than adapting to the imposing constraints of the pre-set palette, P2, P7, P10 and P9 were appropriating it so it fitted with the way they wanted to express themselves. They used it in such a way that they could expand the set of colour options available to them in the moment and express themselves more freely than the 5 pre-set colours allow. For most of them, this process of having to continually pre-set their colours before logging one felt like an unnecessary extra step:

> "*It was a lot harder, in that I had to go in and… well, because you only have 5 colours, once I had an emotion in mind it wasn't ever one of those 5. So I'd have to go in and set a new one and then log it."* (P10, week 2, pre-set palette)

However, P9 saw it as an opportunity to be creative and preview different combinations of colours before she added them to her display:

> *"I did enjoy choosing the colours as well. It was a little creative output for me. I don't know whether it's a control thing, but when I was doing one at a time, I didn't like when they didn't go together.*" (P9, week 6, pre-set palette).

This once again emphasises the diversity in the preferences of participants and how the way they wanted to express themselves through the app tended to shape how they used it.

Data Displays

Four Data Piece Display: Users of the app had access to the home-screen-based four data-piece display throughout the study and the larger all-history data display during the last three weeks of the study (design*p. 125*). It has already been argued that the former was an integral part of the user experience. Findings relating to the *Four Data-Piece Display's* role as a prompt for logging and for reflection have been covered extensively in the logging behaviour section (p. 150) and the reflection section respectively (p.165). This section presents other findings related to the data display and compares the way users interacted with the two displays.

Given that the *Four Data Piece Display* was visibly present every time participants looked at the home screen of their phone, one assumption might be that they looked at it and thought about the colours every time they used their phone. However, in the interviews, participants reported that this wasn't the case. They didn't always see the display, despite its presence. It appears to have fallen in and out of their awareness at different times. P7 described its propensity to blend in:

> *"...it just becomes wallpaper. And so you just like, become accustomed to it." (*P7, week 6)

It appears that participants were more likely to be attentive to what their display was showing if it showed something that had some novelty for them. P6 and P7 both said they noticed the display more often at the beginning of the study than toward the end because it showed something they weren't used to seeing:

> *"It was seeing the background. I think though, you get used to it after a while. The first few days or maybe even a couple of weeks, it was unusual for me not to have the picture on my background. And that would remind me that I was using the app. But after a fortnight, it became normal."* (P6, week 6)

P3 and P9, meanwhile both said that they were more likely to notice the display when it showed unexpected colour combinations: P3, who generally logged similar colours, said he didn't notice his colours when they formed a single homogenous block:

> *"I guess that because I've been putting in the same thing (colours), the background is not as… it doesn't jump out at me as much as it would if there had been, maybe a red in there or a yellow, or maybe a darker"* (P3, week 6)

P9, who generally logged contrasting colours, said the opposite; that she noticed the display more often if the colours *were* a single homogenous block:

"Yeah, I do remember seeing it especially when it was all one colour. So, for example, if it was all black, or all one colour. That was when I would remember and think about that emotion." (P9, week 6, all)

When participants did notice the *Four Data-Piece Display* it could sometimes incite strong reactions. P7 and P9 both described occasions where, having encountered colours that were incongruous with how they felt, they had an urge to change them all:

"There was a day, when I was really, really tired. And I hadn't felt well at all. And so I changed the whole screen because it was too bright. I kept colours that I liked but I went for a more pastel version of it. So it was like, a calmer screen. Not as intense…. it was funny. I was very aware of why I was doing it. I was very aware of feeling quite tired and flat and that the colours were too intense to look at. It was a calmer screen, a calmer thing to look at." (P4, week 2, large palette)

"It was maybe because I saw lots of bright colours on my screen, and I thought this is not how I'm feeling! I was like, I need to change it and I went to the extreme and changed it all to blacks and greys." (P7, week 2, pre-set palette)

Historical overview display: There was a clear contrast between how users interacted with the small-scale display and the overview display. The usage data shows that excluding the time when they first received the overview display during the week 3 interview, only one participant (P2 – 4 times) looked at the overview display more than once. When asked about their use of the display in the interviews, most of the participants said they generally just forgot to use it or didn't feel the need to use it in their logging practice:

"*I looked at it when you first told me about it. But I just didn't end up doing it.*" (P10, week 6)

However, some participants gave more specific explanations for why it didn't fit with how they wanted to use the app. Two of the participants, P1 and P8 said they didn't need to look at longer term data to facilitate how they wanted to use the app:

P8 compared the two displays. He said the quick snapshot provided by the *Four Data-Piece Display* was enough for him to reflect and thus the full report on his data provided by the overview display didn't add anything extra:

> *"I didn't find the overview screen that useful. But I did find this background screen with the few logs [4-colur display] quite useful. It gave me the most recent timeline of what has been going on. And made me think, ok, maybe I need to take action to change things. This was interesting."* (P8, week 1)

Meanwhile, P2, the one participant who did look at the colours on the larger scale display, said that she couldn't remember what they represented:

> *"Yes I did look at that. And I was thinking, these are the colours that I've logged. I was looking at all the walk ones and I was thinking, well which one is it? And I couldn't remember. I go on walks almost every day. And so I couldn't remember which was which. And also, if I was on a walk now, there's not as much to look at. But in Autumn there were gorgeous colours, and I would've just snapped a colour. So that is the main thing I did. Just snapping the moment."* (P2, week 6, all)

Two participants, P4 and P5 said that they found the full history display difficult to understand e.g.

> *"When you first showed this, I found it very confusing. So, I had this negative impression towards it anyway. And then, afterwards it just slipped out of my memory. So, it probably doesn't tell me much about what is going on. For example, I don't know which Thursday it is, which Saturday, which Friday. I'm not sure about how to read it. I find it*

confusing…. Hmm. just looking at it now, I can see that these are the most recent ones, right? (P8, week 6, all)

This indicates that the right-to-left, bottom-to-top timeline structural design might not have been very intuitive for users to interpret. This may be an issue with the design approach chosen here, however it also raises the question of how large volumes of unintegrated colour data, each of which needs to be displayed independently, should be visualised on a small mobile display so they can be interpreted quickly by users.

Finally, there was an interesting observation made by P11 in the interviews. He said that the data display, despite being very visible on the home screen of his phone, protected his privacy. He explained that the ambiguity of the colour-symbolism meant others couldn't read what he had recorded when they saw his phone display; a feature that he liked:

"...on the home screen, it was maybe like... some people would choose a really meaningful picture of a holiday to have on the back of their phone. But for me it was having those positive experiences on the back of my phone that I could look at that was meaningful. But, you know, it was very personal. Somebody else could look at my phone, and they wouldn't know the meaning of those colours. It was very positive feedback from the app." (P11, week 6)

5.4 Limitations and Key Discussion Points

The findings section above has set out observations about how users logged and reflected on their experiences when they used the *Chromatize* app, and their perspectives on the design characteristics of the app. This concluding section of the chapter describes limitations of the research study and then summarises key discussion points related to the findings. This brief summary sets up a broader and more in-depth discussion of the findings from both the *Chromatize* and *SpriteCatcher* studies in chapter 6.

5.4.1 Limitations

The objective of the study described in this chapter was to explore the research space in a more targeted and structured way than in *SpriteCatcher* study described in chapter 3. The research approach implemented was intended to provide the means to more concretely test and build on the preliminary findings in that chapter. This section discusses a number of limitations of the research, which should be acknowledged when considering the findings.

Although the longer duration of the *Chromatize* study (6 weeks) provided a better simulation of how everyday use of a PI technology might take shape than the 3 days of the *SpriteCatcher* study, it was still relatively short to fully simulate this use context. First, the experimental conditions were changed frequently during the first 3 weeks, and so it was only during the last 3 weeks that users could interact with the device without any external interruptions. Second, the study lengths, whether 3 or 6 weeks, were too short to observe how engagement with the device might change over a longer period. There may still be a novelty bias at this point, and users were aware that they were taking part in a study, and therefore may have felt an obligation to engage with the device. So while the research provided a more effective simulation of everyday life-use than the SpriteCatcher study, a longer duration study would provide more accuracy again.

A second limiting factor is that the participant sample is unrepresentative of broader society. Participants were sourced through direct contacts, which indicates that they may be from a similar social background. The sample was also biased toward younger users. There was one participant over 60 and the rest were under 40, with the majority being around 30 years of age. A more representative sample, including a larger range of ages and social profiles, would be required to generalise the claims made in the study.

Efforts were made to collect rich data from the fleeting moments when users interacted with PI devices. In particular, two data collection methods were chosen, because they would help penetrate these moments: an interviewing approach inspired by Petitmengen's *second-person interview method* (Petitmengin 2006) and an experiential sampling system. While these specific data collection methods seem to have added value and helped to obtain rich data, each had its limitations, which should be considered when interpreting the findings.

There is a possibility that, in the interviews, users re-constructed or re-interpreted their user-experiences post-hoc. This is a general issue in interviews that is difficult to avoid. One way to mitigate this is through strategic questioning that encourages users to recall their memories accurately and think carefully about their perspective. However, the second-person interview approach, which was intended to aid this, proved challenging to implement. It clearly takes skill and practice to implement this method, in particular to scaffold the user's attentional focus and move them into the elicitation state that Petitmengin describes - a psychological state in which the individual re-visits the details of a memory. *(see p. 134).*

The experience sampling data helped to provide a degree of corroboration for some of the claims drawn from the interview data. However, it is difficult to determine the weight of the evidence, because it lacks contextual information. Responses were voluntary. Participants could cancel a survey question should they want to. Without knowing anything about the context in which they decided to respond or cancel a survey question, it is difficult to establish

the value of the data. There could have been certain circumstances in which users were more likely to respond to the survey than others, potentially biasing the results. As an example, the survey finding that more users logged experiences when they were at home than at work isn't a concrete insight on its own. It could just be evidence that users responded to the survey most often when they were at home and had free time to do so. The same can be said for the other questions. As a consequence, the experiential survey results should be considered as having provided an indication of certain trends rather than as conclusive evidence of them.

Despite these limitations, there is considerable value in the research. It builds on the preliminary findings from chapter 3 and there is a degree of richness and persistence in the research data that helps to mitigate the limitations. Although, the research is still exploratory, it has provided further indication of the value that experiential logging devices can have for users, articulating a number of patterns and themes that point to this. And while the small numbers and lack of diversity in the population mean the findings cannot be extrapolated across all of society, they provide a good overall impression of which aspects of the research context are of interest and a foundation on which future research can build to explore other user groups and user-contexts.

5.4.2 Key Discussion points

The findings section in this chapter has set out findings related to how users logged and reflected on their experiences when they used the *Chromatize* app, and their perspectives on the design characteristics of the app. This summary of key discussion points now articulates important insights and interpretations of the data. This lays the groundwork for a broader discussion in the next chapter, which sets the findings from this study within the broader context of the aims of this research project and within PI literature and HCI literature more generally.

The key discussion points from the study are:

Reflection: Although participants sometimes used the device purely in an aesthetic sense, picking colours to decorate their phone's display, most of the time they were engaging with the meaning of their experiences when using it. This happened both in the process of logging colour data and when reviewing them on the 4-colour historical display. Participants don't appear to have engaged with meaning when looking at the overview display, indicating that large data displays are not suited to minimalist experiential logging, or that there was an issue with the way that the display was designed.

Although our data suggests that it was common for participants to consider the meaning of their experience in a general sense, which they seem to have found valuable in itself, it appears uncommon for this to then lead to them changing their perspectives or beliefs. When users did experience a shift in perspectives, it was triggered by them focusing on the qualities of their experiences more deeply than they would otherwise have, or noticing relationships between their experiences when logging or revisiting data on the Four Data-Piece Display.

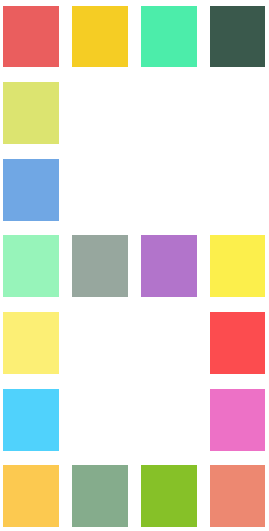
Experiences logged: Participants used the device to engage with a broad set of subjective experiences during their everyday life. This is evidenced both through the way they used the topic-setting feature on the app – gravitating from narrow activity-focused topics toward broader subjective-experience-focused topics - and through the range of different examples of use they described. It is also notable that they focused on experiences that were relevant for them in the moment when using the device, rather than experiences from the past. Even when looking back at data representing experiences from the past, participants never looked back beyond the last few days. This, again, manifests itself in their attitude to the overview display. They didn't find it as relevant for how they wanted to use the device as the shorter term Four Data-Piece Display.

Participants also had a tendency to use the device to engage with their emotions. Most of the topics they chose had some connection with emotion, and in the interviews participants often

related colours to emotional qualities of their experiences when explaining what they meant. In addition to bringing attention to emotional aspects of life, the device could affect how users felt, in some cases helping them to improve how they felt and in others reinforcing negative feelings. The latter seems to have been more common when users were reviewing colours on the Four Data-Piece Display than when they were logging colours.

Logging styles and logging method preferences: In terms of how they logged, the participants can be separated into two camps. One group selected colours in a structured way, seeking to pick colours and associate meanings with them in a consistent fashion. Others logged in an unstructured way, logging without any visible consistency. The former group tended to have a preference for the pre-set palette logging method because it made it simple for them to maintain a consistent logging structure. The latter group had a preference for the capture or large palette logging methods because these were the mediums that gave them the greatest freedom to express themselves through the colours they logged. When forced to use a logging method that didn't naturally fit with their preferred logging style, the participants appropriated the logging method to their preferred style rather than adapt their style. There is one exception, P1, who had a hybrid approach to logging. He combined structured and unstructured logging, switching between them in a fluid manner and using the pre-set palette and large palette in combination to fit with this approach.

Relative impact of the two displays: The Four Data-Piece Display was highly influential in the way that users engaged with the device. As discussed in the preceding paragraphs, seeing the display and thinking about what the colours meant could trigger reflection and affect the way users felt emotionally. In addition, the Four Data-Piece Display was a prompt for participants to use the device. This was particularly important because whereas participants generally only used the device to engage with stark, standout experiences of their own accord, the display prompted them to engage with the more mundane, less intense experiences that are common in everyday life, but which they might not usually think about. By comparison, the larger overview display had no notable impact. Participants forgot to use it or said they didn't find it useful.



6. Designing for Meaningful Engagement with Experiences: A Discussion

This chapter brings together discussion points from across the previous chapters. In doing so, it responds directly to the main question, which underpins the research project as a whole: *How can PI technologies be designed so they support meaningful engagement with experiences during everyday life?* The journey taken in the thesis so far has explored three key concepts (flexibility, minimalist interaction design, and reflection) and their links to different aspects of the main research question. The key steps taken in each chapter are now summarised briefly to set the context for the discussion that follows:

- The literature review in chapter 2 covered examples of how *flexible* PI design features might support *meaningful engagement with experience*s by allowing users to express themselves more openly than typical PI technologies, and how *minimalist* PI design features might support *ease-of-use during everyday life*, by making it simple for users to log and revisit personal data. In the conclusion of chapter 2 a key design concern was articulated: how to strike a balance between expressivity and ease-of-use, hence bringing together the two parts of the aim, *meaningful engagement* and *engagement during everyday life*.

- The explorative research study, described in chapter 3, provided an insight into how users might log and engage with their experiences when they used a PI device, *SpriteCatcher*, which had been tailored for the two concepts, *flexibility* and *minimalism.* The findings showed how the form of the device, the data type, the way users log their data, and how the data is displayed back to them, can affect both *when* users choose to log their experiences and *how* they engage with them. It was discovered that some of the features of the device seemed to support meaningful engagement with experiences during everyday life, while others obstructed it. In addition, the study provided an indication that reflection might be a key process when users engage with their experiences.

- The literature review in chapter 4 discussed *reflection* directly, framing it as a key process through which users can *meaningfully engage with their experiences during everyday life*. The goal of this chapter was to unpack how reflection has been defined and applied inside and outside HCI research, providing a basis for analysing the nuances of how users reflect when they use PI technologies. It was noted that, despite often being cited in PI research, reflection has rarely been well-defined, and there has been little attempt to describe the ways in which different design features affect the way users reflect.

- The research study described in chapter 5 built on the insights about *flexibility* and *minimalism* discussed in chapter 3, through the implementation of another PI technology, *the Chromatize mobile app*, which had been tailored for flexibility and minimalism. The device was designed so it would provide a means to probe how users engage with their experiences during everyday life and to address some of the issues that had prevented users from doing so effectively when using the *SpriteCatcher* device. In addition, the study was designed so that it would provide an insight into the way users reflect when they use such devices. The findings and their implications were only summarised briefly at the end of the chapter. They are now unpacked in detail in this chapter, as the basis of the discussion.

The discussion that follows is composed of three parts, each dealing with one of the key concepts: *flexibility*, *minimalism* and *reflection*. It explores how different minimalist and flexible interaction design characteristics affect the way users engage with their experiences, in the first two sections, and then how different forms of reflection emerge from interaction, in the third section.

Each point made in the discussion about flexibility and minimalism follows a similar structure. Key observations about either flexibility or minimalism are articulated, followed by sub-sections in which design characteristics (data type, data logging method, topic setting feature, device form, data display) are linked to these observations. The reflection section has a slightly

different composition, in that the sub-sections focus on describing the different types of reflection that emerged from interaction.

As set of design considerations in the next chapter summarises the key points from this discussion

6.1 Flexibility

As framed in the PI research literature discussed in chapter 2 (*page 22)*, flexible PI devices are those that give users more control over their data than typical PI devices allow, by leaving the decisions about what to log, and how to log it, with the user. In doing so, flexible PI devices allow users to engage with experiences that are meaningful to them in a given moment in the way that suits them as an individual.

The *SpriteCatcher* and *Chromatize* devices were designed so they would provide flexibility through three different design characteristics:

- *The topic setting feature*
- *The data type*
- *Method(s) of logging*

Drawing on the findings from the two research studies described in chapters 3 and 5, this next section discusses insights about how three flexible design characteristics *(topic setting feature, data type* and *method of logging*) seem to influence how users engage with their experiences. This is structured in two separate sections, covering flexibility over *what* is logged (section 6.1.2) and *how* it is logged (section 6.1.3).

6.1.2 Flexibility over what is logged

One of the key observations that can be gleaned from the two research studies, is that individually and as a group, participants associated a large range of experiences with the colour data they logged - from *the experience of going on a walk,* to *the experience of solving a computer coding problem* and *the feeling of coming home from work on a cold winter's day*. The range and diversity in the examples they gave indicate that users had a good deal of control over what kinds of experiences they engaged with through the system.

There are two key *flexible* design features that appear to have encouraged users to engage with their experiences in this broad way, *open topic setting* and *colour as a data type*:

> *Topic setting:* It appears that open topic-setting encouraged users to engage with a range of different types of experiences (in the *SpriteCatcher* study, participants could choose to engage with whatever experience they wanted in any given moment because there was no topic-setting feature at all and in the *Chromatize* study they set their topic to whatever they wanted). This insight chimes with similar observations made in literature on other flexible PI systems – *Omnitrack* (Y.-H. Kim et al. 2017), bullet journaling (Ayobi et al. 2018) and data physicalization platforms (Thudt et al. 2018). It should be noted, however, that the types of topics that participants chose in the *Chromatize* study contrasts with those chosen with these systems. Because, while users of these systems seem to have set themselves specific, narrowly-defined topics, (e.g., sleep (Y.-H. Kim et al. 2017), mood (Ayobi et al. 2018), meditation (Thudt et al. 2018)), users of the *Chromatize* device set broadly defined open topics, relating to their general subjective experience (e.g*., life and its emotions, things that make me smile*); topics, which in themselves are more open and offer greater flexibility.

> *Colour as a data type*: A second factor that seems to have allowed users to control what they engaged with, and which itself may provide some explanation for why they chose such broad topics with the *Chromatize* device, is that colour, as a data type,

seems to lend itself to broad subjective-experience associations. When the study was setup, participants were told that they were free to set any particular topic that they might like, which may have contributed to the breadth of the topics they chose. However, it also can be owed to the ambiguity of colour as a data type, a quality which gives users a license to express themselves freely according to what makes sense for them as an individual; they aren't limited to expressing pre-defined meanings that are prescribed to them by convention and can associate colours with whatever makes sense to them. Another characteristic of colour data, is that users tend to associate it with emotions. This can be linked to psychology research, which has suggested that there is either a culturally constructed, or an innate link between emotion and perceptions of colour symbolism (Goldstein 2006; Elliot and Maier 2012). Based on these observations there seem to be parallels between colour data and clay-modelling data, which Lee and Hong (2017) have also described as an ambiguous, expressive data type, which has a natural association with emotions. There are also parallels with previous HCI work, which has shown how colour can serve as a medium for expressing emotion, for instance the work stemming from Fagerberg et al.'s study with their Emoto app (Fagerberg, Ståhl, and Höök 2004; Balaam et al. 2010) and Balaam et al. with their Subtle Stone device (Balaam et al. 2010) Adding to this work, the research here has shown the versatility of colour, and how users can apply it in different ways to different kinds of experiences besides just emotions. The research has also shown that when users are given the freedom to choose their own topic and choose how they want to structure the way they apply meaning to colours - without these factors having been controlled or prescribed to them - they can find ways to engage with an array of experiences that are meaningful to them at a given time.

It is important to acknowledge that although the ambiguity and emotiveness of colour data are attributes that allow users to express a broad range of experiences openly, they can also be perceived as drawbacks. Unlike other data types, such as text-entry, colour does not lend itself to describing the individual, practical details of an experience. For example, when P8 logged red to represent the experience of Man Utd losing, he captured the general feeling of the experience when logging the colour red –

itself the colour of Man Utd's shirt. However, this data doesn't contain specific, granular information about the experience and how he felt about the individual performances of each player. There is an open question as to how to balance open-ended expressive logging with detailed granular information, depending on what an individual user requires for a given experience."

Another drawback is that some individuals seem to have a greater affinity with colour than others. There were some users in the research studies who found it difficult to make any associations between colours and their experiences. They perceived colour as an aesthetic quality but not as a symbolic quality. This issue is particularly profound for colour blind users, like the one who took part in the *SpriteCatcher* study, who may lack confidence when associating meanings with colour data. These limitations mean that colour is not a *one-size-fits* all data type. Although, in many cases it seems to be an effective medium for experiential engagement, there are some specific cases in which it is not.

6.1.3 Flexibility over how data is logged

In HCI literature, PI systems have been demonstrated which allow users the flexibility to control *how* their data is logged. Flexible PI systems can allow users to setup their own 'trackers' on an app, complete with personalised data types and fields (Y.-H. Kim et al. 2017), setup bullet journal formats onto which they will jot their data (Ayobi et al. 2018) and choose the materials and presentation format for physicalised data visualisations (Thudt et al. 2018). This flexibility gives users the opportunity to adapt the data logging format to how they want to log and how they want to express elements of the experience-type. So, for example, if a user wants to rate sleep quality, they can setup a data field with a numerical rating scale, allowing them to keep track of their sleep quality over time (Y.-H. Kim et al. 2017) or if they want to record places visited, a map on which they will pin data points (Thudt et al. 2018). (*see image, page 28*).

Participants in the research studies described in this project also appear to have adapted how they logged their data, but in a more subtle way than entirely changing the data type or data field to fit their purpose. This next section labels two different styles of logging that were evidenced, *expression-driven* and *measurement-driven logging*, and then reflects on which specific design characteristics of the device appear to have provided users the flexibility to choose and switch between them.

Most of the users in the two research studies exhibited what we are calling *expression-driven logging*, this is where they selected colours on a case-by-case basis, based on what intuitively felt right in the moment and which expressed the experience best. Their objective was to log their experiences in an open, unencumbered manner, exploiting the openness and expressive license leant by the colour data to gain a sense of meaning. There were two participants in the *Chromatize* study, however, who exhibited what we are calling a *measurement-driven logging* approach. In this case they used colour in a more constrained, systematic fashion, selecting colour data from a fixed set of options, which they felt graded the experience the best. Their objective was to log in a consistent, measured fashion, so they could track changes in their experiences over time.

There are two different *flexible* design characteristics that seem to have leant users the flexibility to adapt the device to their desired logging style, *colour as a data type* and *the provision of multiple different logging methods*:

> *Colour as a data type*: Firstly, colour, as a data type, seems to lend itself to both the *expression-driven* and *measurement-driven* approaches. This is because colours can be encoded with both qualitative and quantitative meanings. *Expression-driven loggers*, perceived the colours they logged as individual symbols, representing the qualities of their experiences (e.g., blue as a symbol representing a visit to the seaside), while *measurement-driven loggers* perceived a set of colours as a quantitative scale for grading their experiences (e.g., a spectrum of colours differentiated by brightness, considered as a rating scale for sleep quality).

Logging methods: The findings also show that different logging methods leant themselves to specific styles of logging. The pre-set palette leant itself to *measurement-driven logging,* because users could pre-set 5 colours in order to create a quantitative scale and make consistent choices from this set scale over time. The *capture* and *large palette methods*, meanwhile, leant themselves to *expressive logging*, because they provided a greater range of colours through which users could express themselves.

Participants in the *Chromatize* study largely stuck to one of the two logging styles throughout. There was one participant, however, who seems to have fluidly switched between them, often logging data in a measurement-driven way, selecting colours in accordance with a pre-set meaning system, but sometimes in an expressive way, choosing one that felt right in the moment. The behaviour of this participant emphasises how simple it is for users to switch between different approaches should they want to do so. They don't have to setup or switch between trackers within the app (Y.-H. Kim et al. 2017) or create new data logging fields or formats (Thudt et al. 2018; Ayobi et al. 2018). Users can simply change the logging method or change their perception of what their data represents to fit their desired logging style. This is important because it provides an indication of how we might design extremely minimalist and flexible PI systems, which can be adapted for dynamically engaging with the meaning of different kinds of experience from moment to moment. Providing data mediums, like colour data, which can be associated with a meaning in a controlled systematic way, but also in a more open, expressive way, seems to provide for these kinds of more seamless transitions.

6.2 Minimalism

Based on the discussion in the chapter 2 literature review, a minimalist PI device is considered to be one that makes logging data (*page 35*) and revisiting it after is has been logged (*page 38)* easy for users, by ensuring that these processes require minimal interaction. The *SpriteCatcher* and *Chromatize* prototypes were designed so that they would embody a minimalist interaction design approach in a number of different ways:

- in the way that users could log their data through simple, single-button interactions;
- in the simplicity and directness of the data display, showing limited data logging history and being positioned on the front of the device;
- in the choices for the form of the device – in the case of *SpriteCatcher* a tangible device, and in the case of *Chromatize*, a mobile app using home-screen-based widgets.

This next discussion section covers three different aspects of the interaction lifecycle, the physical act of logging (section 6.2.1), prompting the decision to log (section 6.2.2) and the act of revisiting data (section 6.2.3), in each case focusing on how different minimalist interaction design features affect when and how users engage with their experiences through such a device.

6.2.1 Simplifying the logging interaction

The *SpriteCatcher* and *Chromatize* devices were designed to make the physical act of logging data as simple and direct as possible. In both cases, there were efforts to ensure that data could be logged with a minimal number of interactions, either by pressing a physical button directly available on the front of the device - in the case of *SpriteCatcher* - or by selecting data from a widget-based interface directly available on the phone's home screen - in the case of *Chromatize*. Similar to the observations drawn by Ferrario et al. (2017) and Choe et al. (2015) in

their work on systems for minimalist logging, users appear to have found the physical act of logging data easy with these systems because they could easily log their data while doing their everyday life activities. However, there are a number of other social and psychological factors that emerged, besides the physical simplicity of the act of logging, which appear to affect the overall perception of simplicity within the everyday life context.

These issues are now discussed with reference to two different minimalist design characteristics of a PI device that affect them, *the form of the device* and *the method of logging provided*:

> *Forms of the device:* Certain forms of device seem to lend themselves to a simpler and more appealing logging experience during everyday life than others, hence supporting logging in a greater variety of situations. When the *SpriteCatcher* device was initially designed, it was suggested that a tangible device form fitted with the minimalist philosophy and would make it simple to log data. Given it was a standalone PI device, it could be tailored from the ground up for simple, direct, single-button data-logging interactions. In practice, however, participants in the *SpriteCatcher* study said that they found it challenging to use this form of device during their everyday life. Its bulkiness made it difficult to carry around and store in pockets and its unfamiliar-look deterred users from logging data in public. This underlines the importance of considering the convenience and social discretion of the interaction design, alongside its physical simplicity. To emphasise this point, in the second *Chromatize* study, when a mobile app form was chosen, there were no complaints about the device. Users seem to have found the mobile app format much more convenient and discreet to use compared to the single-purpose tangible logging device.

> *Methods of logging*: The manner in which users log colour data and how this matches up with their intended style of logging can affect the perceived simplicity of the logging act. Participants in the *Chromatize* study were asked which of the logging methods they preferred, all emphasising the importance of simplicity. However, their perception of

what simplicity meant wasn't determined by the physical simplicity of the logging interaction, i.e., the one that required the least number of taps or button presses. It was the one that allowed them to log in their preferred style the most easily - as explained in the previous section, this could be either *expression-driven* or *measurement-driven* logging. Those who wanted to express themselves most openly with the device preferred the *Capture* and *Large palette* methods of logging and those who wanted to measure their experiences over time preferred the pre-set logging method. It appears that in each case their preference was shaped by which of the logging methods let them pursue their favoured logging style in the simplest way. In the order of priorities, their logging-style preference came first before the physical simplicity of the interaction.

One further point is that the method of logging seems to have had some influence on *when* users chose to log a given experience. The pre-set palette and large palette methods were used to log data sometimes during the experience and sometimes retrospectively. However, the capture logging method, seems to have encouraged users to log data as the experience was unfolding. This was the case both in the *SpriteCatcher* study and the *Chromatize* study. There are parallels, here, with other examples of PI devices that utilise cameras as the data collection tool. For example, Grimes Parker's diet-tracking app (2014), with which users logged their food before eating it. Drawing this parallel, it could be argued that act of logging something from the environment seems to anchor the user in the temporality of the present.

6.2.2 Prompting the decision to log

The *Chromatize* study showed that users sometimes log data about their experiences because they are self-motivated to do so. They experience something and decide to log it because they feel it is important to do so. Interview data indicated that this kind of self-motivated logging appears to happen when users experience an extreme emotion, one of which they are already aware, but which they want to record and make explicit in data. By contrast, subtler, more

mundane, everyday experiences often pass by without it occurring to users that they should log them and without the user necessarily recognising the experience at all. On these occasions, it appears that PI devices can play an important role, by intervening and prompting users to engage with their milder, less noticeable experiences. This is important, because in doing so PI devices can help users to become more aware and mindful of the richness in experiences that would otherwise pass them by. The findings from the research here, suggest that this can be a positive and enriching experience. It can help users to learn about themselves and give them a greater sensitivity to the richness in everyday life. To quote a participant from the SpriteCatcher study, it can give the user the impression that they "lived more,". Notably, participants in both the *SpriteCatcher* and *Chromatize* studies reported that the device helped them to engage with these kinds of experiences more frequently than they would otherwise, and to become more aware of the features of their experiences.

This underlines the importance of design features that draw the users' attention to what they are experiencing and prompt them to log data. There are different approaches to this. A typical solution to this problem with a mobile app is to implement notifications. However, given that this approach didn't seem to fit with the minimalist design philosophy (see page), notification-free designs were opted for. The findings indicate that, despite the absence of a notification system, users were still prompted to log data, in particular by two features, *the device form* and *the four data-piece wallpaper Display*, which acted as passive prompts.

> *Physical form of the device*: In the SpriteCatcher study there appear to have been some occasions when users were prompted to use the device after having felt it in their pocket or after having seen it lying around somewhere in their home. The physical form of the tangible device appears to have lent it a sense of physical presence, which caught their attention.
>
> *Four-data-piece wallpaper display:* In the *Chromatize* study there were a number of occasions when the Four Data-Piece Display on the wallpaper of the user's phone served as a passive prompt. It functioned somewhat like an ambient display, with a persistent visual presence on the periphery of the user's attention. Whenever the user

looked at their phone throughout the day, there was a chance that they would see the display. Because of its constant availability and the simplicity of the data visualisation, it seems to have had what Rogers et al. termed 'glanceability' (2010), subtly drawing the user's attention and prompting the user to log an experience. There was a certain level of spontaneity to this kind of prompting. Rather than demanding engagement at a particular point in time, it proffers an ongoing opportunity for engagement, which means users can be prompted to log at any time, rather than just in the moments when the notification was pre-programmed to be triggered.

It should be acknowledged that based on the evidence from the *Chromatize* research study, it is difficult to say how effective these passive prompts would be over the longer term. There is a possibility that after a while the background would completely *blend-in*, particularly if users stopped logging colours, and therefore stopped renewing its appearance. Likewise, users could become so familiar with the form of the device that it no longer catches their eye. A longer-term study would be required to analyse these effects. However, the study findings do indicate two possible advantages of these kinds of passive prompts over notification systems, at least in the short term. Firstly, they are less disruptive, avoiding a known issue with notification systems. Their ongoing background presence means they don't have to interrupt users to draw attention. Secondly, they can prompt users to engage more spontaneously. Unlike with notification systems, which trigger at certain times, users can notice the passive prompt at any particular moment. This means that users might be prompted in more of the moments that are significant for them.

6.2.3 Supporting revisiting of logged data

Across the two research studies, participants were provided with three different displays through which they could revisit their personal data. In both the *SpriteCatche*r and *Chromatize* studies they could revisit their data on a minimalist *Four Data-Piece Display*, which could be

accessed directly on the front/home page of the device. In the *Chromatize* study, users could also revisit all their logged data on a *Full History Display* by navigating through the app.

The findings from the studies show that out of the three, the participants only revisited their data and engaged with its meaning on the Four Data-Piece Display of the *Chromatize* study. In one respect this challenges the notion that revisiting data is integral to the experience of using a PI device (Li, Dey, and Forlizzi 2010). On the other hand, given that there has been such an emphasis on data as a source of meaning in the PI field, some might question whether devices like SpriteCatcher can be defined as PI devices (note that Li et al.'s definition - "help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" (pg. 558) - doesn't specify whether the reflection must necessarily take place when users are logging data or revisiting it)

Regardless, it is important to consider why users engaged with the data on the minimalist display of the Chromatize device but not on the larger full-history display, nor the SpriteCatcher device, because this can provide an insight into how to provide maximum opportunities for reflection with minimalist PI systems. Three different explanations are provided that relate to specific design characteristics -the *positioning of the Four Data-Piece Display* and *the limited history of the* Four Data-Piece Display and the *simplicity of the 4-piece data display:*

> *Positioning of the Four Data-Piece Display.* One explanation for the greater engagement with the Four Data-Piece Display post-logging, is that it was positioned such that it had a greater general presence during everyday life than the other displays, situated on the home screen wallpaper of the user's phone. While users had to navigate through the *Chromatize* app if they wanted to revisit the *Full History Display* and had to get out the *SpriteCatcher* device and turn it on to revisit its Four Data-Piece Display, they would see the Four Data-Piece Display of the *Chromatize* app spontaneously while using their phone (which as discussed in the previous section meant it had a characteristic "*glanceability"*). Participants didn't always recognise its presence, there were occasions when the display blended in with the other background

features of their phone. However, there were also times when they would notice it, particularly when the colours created an unusual or unexpected pattern. On these occasions they would engage with the meaning of the data and sometimes even feel a strong, almost involuntary, emotional reaction to the colours, prompting them to think about the meaning of the data. This implies that the ongoing presence and availability of a wallpaper-based display could help to support general experiential awareness.

Limited history of the Four Data-Piece Display: Another explanation for why the participants seem to have revisited the Four Data-Piece Display and not the larger all-history display, is that the limited history provided by the former seems to make it more relevant for users during their everyday life. This is what some of the participants said when asked about their use of the two displays, explaining that they wanted to focus on data representing their most-recent experiences. This tendency to focus on the short-term relates to Rooksby et al.'s general notion that users focus on the short-term when they self-track - "*Tracking data is overwhelmingly for use in the short term."* [P. 1171] (Rooksby et al. 2014). It also, corresponds with Mols et al.'s observation that users tend to focus on the *today* when revisiting reflective media, even if the data relates to a previous day.

Simplicity of the four-piece data display: It appears that the simplicity of the 4-data piece display encouraged users to engage with it more than the full-history display. One of the reasons that participants gave for preferring the former, is that they found it easier to read than the latter. This insight builds on the work of Rapp and Cena (Rapp and Cena 2016), who noted that inexperienced self-trackers have difficulty in understanding complex data displays. It should be noted that colour data, in particular might be difficult for users to interpret and understand at scale, because it can't be integrated like other forms of data e.g. numerical data. More work is required to understand how colour data might be made simple and understandable when displayed in large quantities.

6.3 Reflection

This section frames how users appear to have reflected when using *Chromatize* and *SpriteCatcher*.

The research reported has highlighted a distinction between reflection that leads to general self-awareness, affecting knowledge in subtle ways (which will be termed *soft* reflection) and reflection that leads to a shift in perspective on something, affecting knowledge in a more significant way (which will be termed *hard* reflection). The second of these relates most closely to how reflection is generally defined in PI literature, with its emphasis on the role of reflection as a transformational process that incites behavioural change.

This is discussed in more detail in the section that follows: The general role of *soft* reflection is highlighted (6.3.1). Then the specific role played by different forms of *hard* reflection are highlighted (6.3.2). In each of these sections there is an attempt to explain the different ways that users reflect by drawing links to Fleck and Fitzpatrick's and Schön's conceptual frameworks of reflection. As discussed in chapter 4, these particular frameworks provide the means to discuss the nuances of reflection. This is then followed by a discussion about some of the implications of these insights for how reflection should be considered in the PI field (6.3.3).

6.3.1 Soft reflection

It seems that almost every time that users manually logged data in the two studies, they were associating it with an experience in their mind. In the process of choosing which colour to log and what to associate it with, they considered the meaning of what they were experiencing. This was the case with both devices. There were some occasions when they logged something they were experiencing in the present (e.g., when P4 logged the colour of her computer screen to represent a "*too much going on in the brain feeling*" (*chapter 3, p. 70*). And other occasions

when they logged experiences from the recent past (e.g., when P10 logged luminous "*highlighter"* style colours with the *Chromatize* device to represent her having had an out-of-the-ordinary day within the repetition and mundanity of the Covid-19 lockdown).

In addition, participants considered the meaning of their experiences while revisiting previously logged data, focusing on the meanings of individual data pieces or the general experiential landscape of the four colours as a group. It should be acknowledged, however, that this was a rarer occurrence. Users didn't always revisit and reflect on previously logged data.

Although small, fleeting moments of soft reflection don't involve the kind of significant, transformational shift in perspective that has been a focus in PI literature, they can still be valuable for users. Participants in both the *SpriteCatcher* and *Chromatize* studies remarked that they found it useful to check-in with themselves, focusing on the meaning of little moments in everyday life that would usually pass them by. They rarely pointed to an individual insight as being of particular importance, but said they liked the general sense of experiential awareness that they gained from manually logging data, which made them feel like they knew more about their everyday lives than they would ordinarily. It seems, therefore, that the effects of the little instances of soft reflection, though small and insignificant individually, seem to accumulate, and have a significant impact on users' knowledge about their experiences as a whole.

The findings also highlight the significant role that soft reflection can have in reinforcing positive thoughts and emotions. Participants wanted to focus on topics that they found positive, which in turn meant that when they logged data they tended to focus on positive experiences, feelings and interpretations of events. Note, however that when users revisited data this wasn't always the case. It appears that revisiting displayed data can have a negative effect on users, an observation that corresponds with a similar one made by Kelley et al. (Kelley, Lee, and Wilcox 2017).

Soft reflection, as illustrated above, seems to bear the closest resemblance to level 1 reflection (Reflective Description: Revisiting with explanation) from Fleck and Fitzpatrick's conceptual framework (Fleck and Fitzpatrick 2010). One key similarity is that like with our perception of soft reflection, level 1 reflection is perceived by Fleck and Fitzpatrick as a valid form of reflection despite not involving a shift in perspectives. Another similarity is that the process Fleck and Fitzpatrick describe centres around *interpretation* and *description* which seem to be at the heart of what made moments of soft reflection meaningful for users in the research. While logging their data, users in the studies made a choice about which colour to log, and in doing so interpreted the situation. It is in this moment when they described and interpreted the experience to themselves in the form of the data they logged, that users considered the meaning of the experience. However, it should be acknowledged that Fleck and Fitzpatrick's level 1 reflection isn't a perfect correlation. For while they state that level 1 reflection involves a stage where the individual justifies their interpretation of the experience, this wasn't a part of soft reflection. There wasn't a separate stage where users explicitly justified what they had logged. Any attempt to analyse or justify their explanation of the experience was implicitly part of the data selection process.

6.3.2 Hard reflection

Having recognised the role played by softer forms of reflection when users interact, it is now time to analyse the small number of examples that arose which appear to have involved a shift in perspectives. These instances of *hard reflection* are examples which bear a closer relationship to how reflection is usually framed in PI literature.

There appear to have been two different periods during the interaction life cycle when this happened: *reflection while manually logging data* and *reflection while revisiting data*. This tallies with how reflection has been framed in PI literature (Li, Dey, and Forlizzi 2010). The different forms of reflection that emerged in each case are now framed tentatively in this next section, drawing on the conceptual frameworks provided.

The term tentative is employed in the previous paragraph because the evidence for the relationships that are described between the research evidence and reflection types are scarce. In each case there are a small number of examples on which the claims are based. The framing of the interview data that follows should therefore be considered as providing a preliminary indication of some possibilities for how users reflect, rather than a comprehensive account of all possibilities. It is better thought of as stimulus for discussing the relationships between reflection and PI system design than as a precise analysis of these relationships.

Reflection while manually logging data

There appear to be two different forms of hard reflection that emerged when users were manually logging data with the *Chromatize* device. These can be differentiated by the number of experiences that users were thinking about when logging the data, i.e., reflecting on a single experience or multiple experiences, and by their proximity to the present, i.e., reflecting on an ongoing experience in the present or retrospectively on an experience from the past.

> *Reflecting on the relationships between multiple experiences from the past while logging data*: The process of selecting data that summarises a series of experiences over time can give rise to hard reflection. The clearest example from the *Chromatize* study is when P3 would sit on his bed at the end of the day and think about which data piece, from his set of 5 pre-set colour options, summed up a range of experiences from across the day (*page 169*). The process of deciding where, on-balance, his day fitted best on a scale, hence compressing a range of experiences into a single data-piece, caused him to explore the relationships between the experiences in his mind. This is an instance of hard reflection because it resulted in him having a shift in perspective and formulating a more positive attitude to how his day had been.

> This kind of reflective process can be associated with level 2 from Fleck and Fitzpatrick's (2010) conceptual model (dialogic reflection – Exploring relationships).

This is because the user is exploring the relationships between multiple experiences, as opposed to explaining a single experience (level 1 -reflective description). It could be argued that the particular example given above should be associated with level 3, transformative reflection, because the participant said he felt he was generally more likely to think positively about his day while using the device, indicating that a general and persistent shift in perspectives rather than a momentary, transitory one was manifested. However, Fleck and Fitzpatrick's model states that transformative reflection must involve the asking of *fundamental questions* about knowledge, and there is little evidence to suggest that this was the case, or at least this cannot be determined based on the passages from his interviews.

The kind of reflection process discussed here also seems to bear a closer correlation to Schön's concept of *reflection-on-action*, than to *reflection-in-action,* because the user is looking back and considering the meaning of experiences from the past, as opposed to ones that are unfolding in the present (*reflection-in-action*).

Reflecting on the qualities of an individual experience while logging data: The process of logging an individual experience as it is unfolding can also support reflection. The key difference between this form of reflection and the one previously described, is that instead of reflecting on the relationships between a series of experiences, the user is reflecting on the qualities of the individual ongoing experience that they are having in the moment. A key example is when P11 was logging the orange colour of his train ticket and started to think more positively about the situation - *the warmth and comfort of the train* (*chapter 5, p. 168*). In such examples, the colour logging process seems to direct the users' attention to the qualities of the situation, to the extent that it affected their perspective on the situation. The process of logging the colour made the experience explicit in some way, focusing their minds on its discrete features and their broader meaning in-the-moment.

Similar to *soft reflection*, this kind of reflective process can be associated with Level 1 *reflective description* in Fleck and Fitzpatrick's model. The user logs a colour, which they associate with a quality of an individual experience (e.g., the warmth of the train), explaining their interpretation of the experience back to themselves. It is the process of logging and interpreting the colour that draws the meaning out of the experience. However, there isn't an exact correlation to Level 1 from Fleck and Fitzpatrick's model, because in the case of the reflective process described here, logging the data brought about a shift in perspective, which is a divergence from Level 1 reflection. There are also parallels with Ayobi's notion of *self-tracking* as a mindful practice. The act of logging data by choosing and then capturing a colour from an object can be perceived in a similar way to how Ayobi et al. see the creation of bullet journaling; as a mindful form of data creation (Ayobi et al. 2018). The process of carefully choosing how to create the data draws the user's attention to the features of the experience. There is a sense that the user is experiencing some fresh details in something that they wouldn't have otherwise noticed. As Ayobi frames it in their thesis – drawing on Langer's concept of mindfulness – the user is drawing novel distinctions within the experience they are logging, it therefore enables them to "*develop sensitivity, adopt alternative viewpoints, adapt to constant changes in life and, therefore, fosters the experience of control.*" (pg. 149) (Ayobi 2020)

Given that the user is reflecting on an experience that is unfolding in the moment and they are still a part of the experience, the kind of reflection just described can also be associated with Schön's concept of *reflection-in-action*. The act of reflecting on the situation affects their perspective on the situation as it unfolds, manifesting what Schön calls *back-talk*, the dovetailing of action affecting reflection, which in turn affects action.

Reflection while revisiting data

Taking only examples in which there is evidence to suggest that the reflective process affected a shift in the perspectives of the individual, there appears to have been just one form of reflection that emerged when users revisited data on their display. This was when users explored the relationships between the individual pieces of data on the *Four Data-Piece Display* on their phone:

> *Reflecting on the relationships between data displayed on the Four Data-Piece Display:* There were a handful of examples of this form of reflection in the research. One of these, is when P6 noticed how well she had been sleeping after looking at the data on her phone (*chapter 5, p. 170*) . She synthesised this knowledge with her own contextual knowledge to draw the insight that she was sleeping better because she was on holiday, rather than at work. One of the notable outcomes of this form of reflection is that insights drawn from the relationships between pieces of displayed data could incite users to take action and adapt their behaviour. P1 and P8 both spoke about having looked at their display and realised that the pattern of dark colours meant they had experienced a series of negative events in a row, which then spurred them on to do something positive and address the trend (*chapter 5, 171*).

Once again, this kind of reflective process can be associated with *level 2* (*exploring relationships*) from Fleck and Fitzpatrick's conceptual framework because the user is exploring the relationships between multiple experiences represented by their data. Some might argue, that because users chose to *do something positive* and change their behaviour after noticing the negative connotations of their data, this is an instance of *lv. 3. transformative reflection*. However, the process doesn't seem to have involved deep reflection on the fundamental reasoning behind the data. It was more about them becoming aware of their mental state, than a fundamental shift in thinking. As a result *lv. 2* seems a better fit. The way users reflected when they revisited data can also

be associated with Schön's concept of *reflection-on-action,* as opposed to *in-action,* because the user is looking back and considering the meaning of experiences from the past represented on their display.

6.3.3 Implications of the framing of reflection provided

This next section covers some different implications that the framing of reflection above has, with respect to how reflection has been framed and discussed so far in PI literature. The first section focuses on implications for how specific aspects of reflection are portrayed in PI literature. The second section focuses on the broader implications that the *soft/hard* reflection framing approach might have for the PI field.

Specific implications for PI literature

Three key points are made about the specific implications of the way reflection has been framed, covering the way *reflection-in-action*, *reflection at the time of manual logging* and *reflection on displayed data* are perceived in the PI field:

First, focusing on *reflection-in-action*, in PI literature there has been a tendency to explain how reflection emerges when users log data by associating it with Schön's concept of reflection-in-action (Epstein et al. 2015; Ayobi et al. 2018; Thudt et al. 2018). Based on the framing of the data presented above, however, it can be argued that users can not only *reflect-in-action* when they log data, but also *reflect-on-action*. Which of these takes place is dependent on whether they are engaging with their experiences in the moment or retrospectively when they log the data. If users log data that represents an ongoing experience, they are reflecting-in-action, but if they are looking back into the past and logging data that represents experiences that have already happened, they are reflecting on-action. This is an important distinction to make because of the different effects that these two different forms of reflection can have on users.

When *users reflect-in-action* while logging data, they are in a position to intuitively act on what they have learned as it is ongoing. Their use of the device can affect the individual experiences as it is unfolding by, for example, *helping them regulate their emotions or improve their mindset*. When users reflect-on-action while logging or revisiting data, meanwhile, the experiences they are considering have surpassed, so they cannot be directly affected. However, users can take a minute to summarise, analyse and reflect on multiple experiences as a group and therefore explore deeper reflective insights by bringing together different pieces of information.

Second, focusing on *reflection through manual logging*, when this has been discussed in PI literature, there seems to have been an emphasis on the data itself as focal points for reflection. This is how it has been presented in Thudt et al.'s paper (2018) for instance, in which they point to the physical manipulation of data-creation materials as a catalyst for reflection. It is also implied by Ayobi et al. (Ayobi et al. 2018) when they talk about users reflecting while adding and reviewing data simultaneously on a bullet journal. The framing of reflection provided here has suggested that in addition, the process of thinking about what to log before the data has been created, can be a focal point for reflection. This happens specifically when users are condensing a series of experiences into a single data point and deciding how they might sum up the theme in a single data-piece. There is also an indication that users don't even need to do the physical act of logging the data, to reflect on it. If users get into the habit of logging and reflecting on data they might start to do this solely in their mind by associating colours with their experiences even when they aren't interacting with a device.

Finally, focusing on *reflection on displayed data*: This has generally been presented as a process where users reflect on large-scale data in PI literature. The integration of the data and the story that this tells have been perceived as the focal point of the reflective thinking (Li, Dey, and Forlizzi 2010). The framing of the research data above, however, showed that, when users are presented with a simple visualisation showing a small number of data points, they can reflect on the relationships between these individual data points, and draw insights from these relationships. Furthermore, the insights they draw from this can be powerful enough to prompt

the intention to change their behaviour (e.g. to reflect on data with negative connotations and consider doing something positive to address a chain of negative experiences), although note that this doesn't necessarily mean they did change their behaviour. This builds on existing research, in particular, that of Cordeiro et al. (2015), that has pointed to the value of simple displays, which provide data that can be re-experienced directly, and that of Rapp and Cena (2016), who have noted that simple displays can be used for quick reflective insights during everyday life and are easily understood by less data-savvy users.

Broad implications of the soft/hard framing approach

The way that reflection has been presented above has potential implications for how it should be perceived conceptually in the PI field. A first key point to note, is that soft reflection emerging from manual data logging, appears to play a more important role in the way users engage with and learn about their everyday lives than has perhaps been appreciated in PI literature. Although moments of soft reflection have little significance individually, they can emerge frequently and can have a valuable effect on self-knowledge as a whole; raising users' general sense of awareness of the experiences that populate their everyday lives.

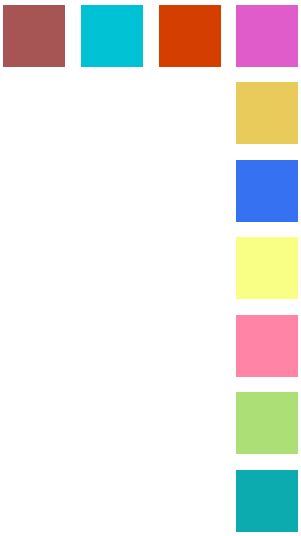
By contrast, examples of hard reflection can be very sparse, in particular instances of critical or fundamentally transformative reflection, the kind of reflection that most PI literature focuses on. One general factor that might go some way to explaining this, is that it is challenging to develop a methodology for pinning down clear, concrete examples of how users reflect. It is possible that there were more instances in the user study when users performed *hard reflection* than is implied by those reported on, and that participants were unable to recall or describe them all clearly in the interviews. A second explanation is that the particular system designs trialled in this study, given their extreme flexibility and minimalism, weren't as conducive to transformative reflection as typical PI system. A third, and perhaps the most profound possible explanation, is that during everyday life it is actually rare that people have moments of significant, transformative insight where they consider the fundamental basis of

their beliefs in light of evidence. This reflects Slovak's claim that transformative reflection is hard and rarely emerges from users simply being exposed to data (Slovak, Frauenberger, and Fitzpatrick 2017). It also relates to Choe et al.'s observation that lower levels of reflection from Fleck and Fitzpatrick's framework (levels 1 and 2) are more common than the higher one (levels 3 and 4).

Given the focus on data as a stimulus for behaviour change in PI literature it is understandable that there has been a lot of focus on hard, transformative reflection in the past and less attention on the role of manual logging as a stimulus for soft reflection. It seems that the utilitarian focus in the PI field, with its emphasis on behaviour change may have had a limiting effect on the scope of PI research (Rapp and Tirassa 2017). It is important, therefore, to broaden the scope in PI and consider the value of a range of different forms of reflection emerging from different kinds of interaction, including manual data logging and other forms of interaction, and how they can serve users in different ways; supporting behaviour change but also self-knowledge development more broadly.

A third point, again relating to the soft/hard framing of reflection is that *soft* and *hard* as two different categories of reflection could provide a helpful way to organise different types of reflection so they can be discussed more easily in PI literature. Differentiating between soft and hard reflection, by determining if a user has experienced a shift in perspectives, is relatively simple compared to establishing which of the complex processes and subprocess in Fleck and Fitzpatrick's model are manifested. It can be determined based on participants' descriptions of what happened when they used a device and what affects it had on them and doesn't require the same degree of interpretation as determining whether a user is *asking fundamental questions* as a sub-process of transformative reflection (Fleck and Fitzpatrick p. 218). There is some discussion to be had within the PI field about the precise definition of a *shift in perspectives*, however, the *soft/hard* categories could serve as an effective starting place from which to start discussing how different forms of reflection emerge from different forms of interaction.

A further advantage of the soft/hard differentiation, which relates back to the point made earlier about the importance of bringing softer forms of reflection into focus, is that it puts all forms of reflection on an equal footing. Fleck and Fitzpatrick's model, by ranking different forms of reflection by numerical level, gives precedence to critical and transformative reflection, downplaying the importance of the lower-level forms of reflection. The soft/hard terminology might therefore encourage researchers to see softer forms of reflection as more valuable within the PI field.



7. Design considerations, Future Work and Conclusion

The previous chapter discussed a range of insights relating to the overall aim of this project: to understand how PI technologies can be designed for meaningful engagement with experiences during everyday life. This chapter now builds on this discussion by setting a trajectory for designers and future work in this arena. This unfolds across three sections: design considerations (7.1), future work (7.2) and conclusion (7.3).

7.1 Design considerations

The research in this dissertation has emphasised the value of flexible design characteristics which allow users to tailor systems to their individual needs, in terms of how they want to log and revisit their data. It has also emphasised the value of minimalist interaction design, which makes it easier for users to log and revisit data while on-the-go during everyday life. Finally, it has highlighted the role that different forms of reflection can play in experiential logging.

The statements that follow unpack some of the key elements of these broad insights, as a set of considerations that can inform the design of PI technologies for meaningful engagement with experiences during everyday life:

1 *Flexible design characteristics* (e.g., open topic setting, expressive data types and multiple data logging methods) provide the freedom for users to engage with the experiences that matter to them in a way that makes sense to them as individuals (6.1.1, p. *196*).

2 Due to its ambiguity and emotiveness, *colour data is a rich symbolic medium* through which users can engage with their felt subjective experiences (6.1.2, p. *129*).

3 *S*ome users find it more valuable to log experiences in an unstructured, expression-driven fashion, others in a more structured measurement-driven fashion. Systems can be designed so users can *easily choose and switch between styles of logging* (6.1.2, p. *199*).

4 *Direct manual logging interactions* are valued by users because they enable them to log data while engaged with everyday life activities (6.2.1, p. *202*).

5 *Simple, discrete forms of device and interaction design* are valued by users who don't want their experiential logging to draw the attention of others in public (6.2.1, p. *203*).

6 Users value physical simplicity, but not at the expense of being able to log in their preferred style. Therefore, there is a balance to be struck between the *simplicity and flexibility* of the logging method (6.2.1, p. *203*).

7 The way users prefer to log their experiences affects their perspective on simplicity*. There isn't a single best approach to simplification* (6.2.1, p. *203*).

8 Design features that give the device a *physical or visual presence* subtly encourage users to log and revisit their data by prompting them to engage (6.2.2, p. *204*).

9 Simple, *small-scale data displays with limited history* are relevant for users because they show the data in which users are most interested - their recent experiences (6.2.3, p. 204), and are meaningful for users, because they are a source for quick reflective insights during everyday life (6.3.3, p. *217* – specific implications).

10 *Soft and hard forms of reflection* are valuable, each contributing to self-knowledge in a different way. Interfaces for manual data logging support both forms of reflection (6.3.3, p. 193 – broad implications).

7.2 Future work

Avenues for future work build on the research reported. This section outlines examples of future work, focusing on design properties related to flexibility and minimalism. It then discusses work relating to reflection, research approaches and finally diverse user populations.

Flexibility and minimalism

One of the ways in which future work could build on the research insights from this project directly is through further investigation of how flexible and minimalist design characteristics affect the way that users log and engage with their experiences. This might lead to a better understanding of how we should design PI technologies for meaningful engagement with experiences during everyday life.

How can logging with different flexible data types support meaningful experiential engagement with PI systems?

The research in this project has shown that colour data has the flexibility for users to express their experiences openly. A range of different properties of colour data have been described which affect how it is used (p. 196). These insights have been drawn from research which has only covered a limited number of different ways that users might log and revisit their experiences using colour data – four different logging methods and two ways of visualising colour data. Future research could explore alternative, unexplored ways that users might engage with colour data, focusing on alternative ways that users might log it and alternative ways that it might be organised and presented to users. Furthermore, future research could drill further down into the different ways that users can associate their experiences with colour data. This research might illuminate some other properties of colour data that weren't detected in this project.

A further step, which broadens the focus some more, however, would be to investigate the properties of alternative data types besides colours data, which might also be used for flexible, manual logging (e.g., novel forms of text-based data, shape-based data or gesture-based data). This might reveal how systems can be tailored for the needs of different users in different contexts, so they are able to express their experiences with data in a way that makes most sense to them.

How does the mode of interaction affect how users log?

The research in this project has hinted at relationships between the data logging interaction and the way that users engage with their experiences. One observation was that users tended to engage with present ongoing experiences and focus on elements of their environment when logging through the capture method (e.g., the participant who captured a "wooden table type feeling" in the *SpriteCatcher* study (*chapter 3, p. 70*) and the participant who captured colours from their walks in the Chromatize study (*chapter 5, pg. 168*). It has been suggested that this behaviour is a product of the way the capture logging method orients users toward the world; that logging methods which orient the user toward their external environment, rather than the digital environment of the device, anchor them in the present moment, bringing about a sense of *immersion in the world*.

Future work could explore this theory: A series of different kinds of logging methods could be compared, which orient users toward different aspects of reality. Conventional logging methods that orient users toward a digital device (e.g. logging data using the touchscreen of a phone app), could be compared with other logging methods that orient users toward aspects of their external environment (e.g. a device that amplifies and logs the sounds made by objects when users tap on them) or methods that orient users toward themselves (e.g. an on-skin interface (Kao et al. 2018) with which users log experiences by touching their own skin). This might provide the means to investigate how the logging interaction, and in particular how it orientates users toward different aspects of reality, might affect how users engage with their experiences.

Reflection

What effect does soft reflection through manual data logging have on self-knowledge and how can we tailor designs for it?

The research conducted in this thesis has characterised some of the different ways that users can reflect when they use PI technologies, underlining the potential value of soft reflection when users manually log data. There is some evidence that moments of soft reflection enhance users' experiential awareness, and that over time this accumulates and helps them to develop greater self-knowledge. Further research might build on this by unpacking the relationships between soft reflection, experiential awareness and self-knowledge and exploring how systems can be designed to support soft reflection.

One aspect of soft reflection brought out in this thesis, is that it is often a product of manual data logging. With both the *SpriteCatcher* and *Chromatize* designs users could only revisit a limited amount of previously logged data on the display, which may have brought this into focus. To gain a further insight into the role that data logging plays in fostering soft reflection, it may be useful to carry out research with PI system that restricts users from revisiting their data for periods. Or a set of devices which vary the amount of data that users can get access to and how they get access to it. In doing so, the research might provide a lens onto reflection-through-manual logging specifically, by isolating it from reflection-through-revisiting-data.

Taking this a step further, it would be interesting to explore different ways that systems might support soft reflection without users having interacted at all. The interview with one of the participants in the *Chromatize* study indicated that he found himself logging and considering the meaning of his experiences in his mind, even if he didn't log data about them. Simply being aware that he had the device seems to have given rise to soft reflection. Speculating about this example, future research could explore whether there are ways for systems to foster soft reflection beyond physical interaction.

Research Approaches

How can rich, accurate data about moments of micro-experience with PI technologies be collected?

The research carried out in this project has provided an indication of how to get access to the small, fleeting moments of micro-experience that emerge when users have experiential logging devices. Primarily asking '*what*' questions in interviews, which prompt users to recall and explain a memory, rather than *how* and *why* questions, which tend to result in users analysing and generating an opinion on it, seem to elicit rich, well-grounded responses. When asked these types of questions, users tend to focus on recalling the individual details of the memory first, before making an attempt to evaluate what it meant for them, providing a more solid foundation for their thoughts.

These are preliminary observation, however, and it is still unclear what the best approach is to collecting rich data in this context. Future research could investigate these ideas further, exploring how different approaches to questioning can be used to probe what users are experiencing in the fleeting moments when they log and revisit their data. This could include further attempts to explore how the second-person method (Petitmengin 2006) might be implemented most effectively in this context. Furthermore, it could investigate how an experiential sampling approach can be developed which addresses the issues that were reported in the limitations section of chapter 5 (p. 189). In addition to supporting the PI field, this research might build on work that is exploring the potential of digital experience sampling methods more broadly (Berkel, Ferreira, and Kostakos 2017).

Diverse User Populations

The focus in this thesis has been on experiential logging for the general population. It is worth considering whether the value of such logging is as meaningful for specific user populations. During the planning phase for the *Chromatize* research study, we spoke with art therapists who run art groups, and demonstrated the *SpriteCatcher* device for them. They suggested that it might provide a useful means for people who participate in group art therapy to evaluate sessions. They explained that attendees generally don't know what to say when asked to evaluate sessions and that the simple open-ended experience logging with the *SpriteCatcher* device might provide an outlet for them.

This indicates that there might be opportunities to apply experiential logging devices, similar to *SpriteCatcher* and *Chromatize,* outside of the *experiential logging during everyday life* context. In particular, it emphasises their role as an outlet for emotional expression and sense-making. By providing a means for people to log their thoughts and emotions non-verbally, such devices might support the needs of users who find it challenging to express their emotional state in words.

There are a number of other settings in addition to group art therapy sessions that might be explored. For example, experiential logging devices could be implemented as educational tools that might help children develop their emotional awareness and intelligence. Colour data, in particular, might be a medium of expression that resonates with children who struggle to find a way to make sense of their emotions (Pope, Butler, and Qualter 2012). The use of experiential logging devices could also be explored in mental healthcare settings, as tools that people suffering with mental health problems might use to identify and make sense of their experiences.

Given the specific characteristics of these populations, this kind of future work would require substantial focussed investigation of the needs of users. Collaboration with psychologists and educators might be necessary to tailor systems to a given setting.

7.3 Conclusion

This research has investigated the design of flexible, minimalist interactions for experiential logging in everyday life. Rooskby et al. (2014) noted that users can have different motivations for using PI systems. However, applications of PI technology had generally been designed with a much narrower purpose than general experiential engagement, only providing the means for users to engage with data about specific areas of their life (Rapp and Tirassa 2017). And while recent research had shown how flexible PI systems might allow users to track different aspects of their life more openly and provide the means for users to develop and evolve their tracking practices over times (Ayobi et al. 2018; Thudt et al. 2018; Y.-H. Kim et al. 2017; Lee and Hong 2017), these haven't supported flexibility in the extreme extent that has been discussed in this thesis – switching the approach on an instance-by-instance basis to engage with the fleeting subjective experiences that are meaningful in a given moment.

This empirical research has provided evidence and insights demonstrating that experiential logging devices do have value for users. Some people use these systems in an unstructured way, focusing on expression-in-the-moment, and making systematic longer-term reflection more difficult. However, by providing a medium through which users can engage with the immediate subjective felt experiences that matter to them as individuals, they bring users closer to the richness and qualities of their everyday life. Users appreciate it when this involves reflecting and formulating a perspective on a given aspect of their life. They also value the general experiential awareness they gain while logging data about experience.

The thesis has demonstrated the important role that flexible, minimalist design features play in enabling users to engage meaningfully with their experiences during everyday life. Everyday life

experiences are diverse and personal to each individual user. Users therefore have their own individual preferences for how they want to engage with them though an experiential logging device. Manual logging of flexible data types, which users can adapt to suit different kinds of subjective experience on-the-fly, allows users to engage freely with the experiences that matter to them as individuals in the way they want. Simple, direct logging methods and data displays, and features that give the system a physical presence, reduce barriers to engagement – making it easy for users to log, revisit and reflect on their data while going about their everyday business.

In the context of a quickly-evolving PI research field, this research provides evidence that experiential logging devices could be valuable members of a family of different types of PI system which have diverse characteristics and serve different purposes. Framing the PI field in a broad, rather than narrow, way (Rapp and Tirassa 2017), provides space for the exploration of alternative, experimental designs and applications that are conducive to rich reflective thinking – both hard and soft.

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Appendices

Appendix I: Chapter 3 - Semi-structured interview questions for study 1

How did you find using the device?

What did you do with it?

Would you mind showing me an example of how you used it?

What did you use it for?

How did you use it?

Where did you use it?

Can you talk me through the process of using it?

Where did you keep the device?

How would you improve the device?

Did you think of the colour first or look for a colour first?

How did you feel when you used it?

Appendix II: Chapter 3 – Thematic analysis of interview data from study 1

Theme 1: Aspects of experience logged

A Sensation-centred experience	**1** *I went to the florist and there were a lot of pink flowers. I took several different pink flowers. It wasn't really an emotion it was a sensation. The colours were beautiful I liked them. But I can't really explain why I felt the desire to capture them. Sometimes I know why I capture a colour because it represents an emotion. Other times it is just a desire which I can't explain [p1].* ***2*** *I like pink and so I like capturing the different shades I created a mini rainbow of the same colour [p1].* **3** *I took lots of clothes, lots of different materials and fabrics [p3].* **4** *I pushed the button because a colour was like a firework in my eyes. Yesterday my daughter arrived with very red pyjamas on. I thought, woah it's really red so I took the colour of the pyjamas [p5]* **5** *Most of the time I was looking for colours that impressed me and recorded them in the device. I'm thinking that most probably the colour that I clicked, were colours that I am not used to in the given situation [p5].* ***6*** *I capture bright colours that I like - [lists] green, yellow, red, pink, orange. I love navy blue. It's not a bad colour for me. [p1]* **7** *I like to take pretty colours [p3]*

B Emotion-based experience	*1 I had a shower and I put my pyjamas on in the bathroom and there were nice, calming colours and I just felt really relaxed and I thought, right, I'll capture this as well [p2].* ***2** I used it at work, actually it was difficult. I think I was feeling like I had a lot of information in my brain. It was like that kind of "eeeeeh feeling', a too much going on in my brain kind of feeling. And so I was trying to take a picture of the colour of the screen. It was more me feeling something and then trying to find the colour for that. Or maybe it was the object. It was like the screen that I was looking at [p4].* ***3** I was by the fire and I took yellow, I felt good. [p1]* ***4** Grey. When it was raining. (Screws her face) Only once I took grey [p1]* ***5** After my visit to the hairdresser I was not happy at all. I was searching for the colour red and I felt better [p1]* ***6** I used it when I got back from the park. I was feeling revitalised from being out in the fresh air. I captured a green colour from something in the kitchen that conveyed that. Because I was feeling full of fresh air [p4].* ***7** My son didn't want to eat something and I showed it to him and I said, "look, I took dark pink". Because I am not very happy. He watched me with his big eyes [mimics his reaction] and I felt more calm I think [p1]* ***8** To begin with it was getting up, how do I feel when I get up. Well, on Saturday morning I didn't feel too good because I'd had too much to drink on Friday night. But it did focus my mind on thinking, well, I shouldn't have really done that. It was a case of trying to find a colour that matched that. It was like hardwood. It was a hardwood, mahogany colour[P8]* ***9** Yesterday I was quite upbeat, so it was a red wine bottle. It wasn't the object, the wine bottle, it was the association of the red wine with the day. [p8]* ***10** Sometimes, because I had a moment to think about how I feel maybe. I think "Ok, I feel like this or that, is there a colour that I can match with that [p3]"* ***11** Sometimes I do it when I think, ahh it's a nice moment that I'm living right now. So let's take a picture of this situation. I took the colour that was close to me. [P5]* **10** *I use it when I am happy or angry. Or tired too. I take navy blue for example [p1]* **11** *Today I was at the train station and I was feeling good and I thought agh! I really wanna scan this colour. I was in kind of a good mood and I was like ok [p2].* **12** *Yesterday and today was nice and sunny because the room was full of light and everything was bright and that made me more interested in it. There was a day when it was really cloudy outside. It was grim in the house. So, the colours were not bright. Nothing was that interesting. That was when I was not too interested in scanning too much [p2].* **14** *I did a few during the course of the day. I was putting the shed up and it was a case of being happy to be at the end of it. [p8]*

C Activity-based experience	**1** *I was by the sea and so I captured blue [p1]* **2** *Blue because I went to the swimming pool [p1]* **3** *I tried to use it at different times. I thought it would be important to capture the colour in the morning because I'm not a morning person. And then after I've had my coffee and I'm ready to go out, I scan it again* [p2] **4** *I took lots of clothes, lots of different materials and fabrics. Because I was making my suitcase for going on holiday. It was a positive experience [p3]*

Theme 2: Logging and Colour Meaning Association

D Colour-Association	**1** *I capture bright colours that I like - [lists] green, yellow, red, pink, orange. I love navy blue. It's not a bad colour for me. Pastel pink is love, softness. Fuschia is more lively* [p1] **2** *You will be surprised by my choices because they don't follow the clichés. For me black is positive, it means power.* [p2] **3** *I felt more positive when I captured colours. Colour for me is associated with positivity. There are no colours for negativity. For me colour is pretty. The same with black; it's pretty. Even sombre colours. There are no negatives* [p3] **4** *It's easier to describe feeling with colours. Colours are spontaneous. I just take the device and I think this colour (picks up the device and demonstrates). I don't think so much. When you use words, it is different. Except when you are angry. Yes, I think it's more easy the colours.* **5** *It felt good. particularly if I was trying to find a colour and I found a colour that felt right for how I was feeling."* [p4]. **6** *It was good for me because I'm not very good with words. It was very visual and that was good for me* [p4]. **7** *A few days down the line, you've forgotten what a particular colour meant"*[P8] **8** "*It was all about trying to record stuff that was around you. It isn't a graded sort of thing. All it is recording is how something happened at a particular point in time.*" [P8] **9** "I*t fits with where you are, what you're doing, how you're feeling. if you had to label how you're feeling maybe you would call it anger but there are different types of this emotion. Every time you're feeling anger you might not use the same colour. Also, you might not be able to find red*." [P4] **10** "*I found the selection the most difficult part because I struggled to relate a colour to particular events. So, for instance, when I was in the bathroom, and I was pleased to have lost a bit of weight, it was like. Well, what's positive? Green, let's say. because green was a positive sort of colour."*[P8] **11***"Trying to contrive what would be the most relevant colour. So what I thought at the time, was that the most positive colour would be the green of the towel." I just went for the towels because they looked green, although my wife says they are yellow. but, as you know, I'm colour blind."* [P8] ***12*** *"I often wanted to take not only colours. But sometimes fabrics and materials" [p1].* ***13*** *"I also used it to check how it would show a colour when I found a very strange colour in my environment" [p5]*

Theme 3: Experiential engagement

E Reflection	**1** *I like choosing a colour for my emotions it helps me to understand* [*p1*] **2** *I think it's exciting to test colours and to think about colours and think, "ah yes, this colour is good or sad". We don't think about this often, it's special [p3].* **3** *It was quite hard because it's not something I normally do, is registering how I'm feeling. Normally, I'm like, I've got stuff to do or I need to be somewhere. So, I think forcing myself to take note of how I was feeling at different times was good* [p4] **4** *When you reflect on your past day it's important moments when you can summarise. I have added an event to recall. Big events - I had an interview, I ran this amount at lunchtime, and I clicked the button in the supermarket. It becomes another moment to recall in the day. It makes me realise that I am alive [p5]*

F Awareness	**1** *When you use this, you are more attentive when you look at the things around yourself* [p3] **2** *The colours that I clicked, were colours that I am not used to in the given situation. Or colours that I did not notice previously. But on that day, I really notice that they are there…. I am much more focused on the colour of things than normally when I don't have the device. Because I am looking for situations when it is interesting to push the button.* [p5] **3** *It makes me think that I live more than usually because I have more memories. In particular, it is the free time that we totally forget* [p5].

G Regulating emotions	**1** *After my visit to the hairdresser I was not happy at all. I was searching for the colour red and I felt better [p1]* **2** *Gaspard didn't want to eat something and I showed it to him and I said, "look, I took dark pink". Because I am not very happy. He watched me with his big eyes [she mimics his reaction] and I felt more calm I think* [p1]. **3** *It felt a bit like. Oh, I've done that now. I can move on. Particularly if it was a negative emotion. It was like, I've done that now. Life carries on, kind of thing* [p3] **4** *I felt more positive when I captured colours. Colour for me is associated with positivity. There are no colours for negativity. For me colour is pretty. The same with black; it's pretty. Even sombre colours. There are no negatives* [p3] **5** *I used it probably when I was feeling either more positive than normal or less positive than normal [p4]*

Theme 4: Usability

H Inaccuracy of colour mapping	**1** *I was disappointed because the colour displayed does not always match with the colour I wanted to capture. It's not exactly the same colour (demonstrates by trying the device on the brown wood of the table) [p3].* **2** *It's difficult because of the glass, it doesn't, like, pick up the colour* [p4] **3** *The colour is not so accurate. Maybe having a real camera for taking not only colour but also a shape. Even the reality. This could match better with what you want to record* [p5].

I Attentional demands	**1** *When I'm at uni I can't just pick it out during a lecture because I'm concentrating on something. Or on the train I'm reading something and I'm distracted again. I may not be monitoring that much how I'm feeling*. [p2] **2** *I took it in my bag so I used it at home and also in my car. At work not so much, maybe one time. When I am at work I have no time to do this* [p3]. **3** *I think I just remembered more at home. I got it out of my bag. But when you're on the go, it's more difficult to remember, because you're either doing something or trying to get something done* [p4]. **4** Dur*ing my work hours, I used it a few times, but it was between two different tasks. Or when I come back from a coffee break. But I never stopped a task to do it. When I have a break or I am moving from one place to another I use it. At the supermarket I was waiting at the cashier and I used it [p5].*

J Size, portability and convenience of use	**1** *I used it a lot when I was at home. I could pick it up easily because I had it with me. But when I was at uni I really had to think hard about where is the device* [p2]. **2** *If this application was available on an iphone it would be better. We have the phone on us and it's easy to access. This though, no, it's too big* [p3] **3** *You might not have your bag with you and you might want to use it and you don't have it on you. Because it's something that you need to keep with you. It needs to be quite easy and small* [p4] **4** *It would be in my bag or in a pocket. Or in my purse, or attach it to yourself, like a watch [p4].* **5** *I had it for the 3 days always in my pocket, or nearby my bed. It stayed with me. I used it at home, at work, on the metro* [p5]

K Privacy	**1** *Today I was at the train station and I was feeling good and I thought argh! I really wanna scan this colour! I was in kind of a good mood and I was like ok. Who's looking at me now. If it became common and everyone had one nobody would think twice about using it in public[p2]* **2** *I did use it at work, but it's a bit more awkward, because you're out in the open plan desk area, and people can see what you're doing [p4]* **3** *When I used it in the supermarket I found a red/orange colour. I looked at this colour but I made it very quick, to avoid people looking at me and saying "what is it that he's doing with the device? what is it for? It felt a bit like I am stealing the colour [p5].*

Appendix III: Chapter 5 – Semi-structured interview questions for study 2

Interview A (Days 7, 14, 21)

So, how's it going?
Can you talk me through an example of how you used the device? Where were you? What were you doing? Why did you choose to use it at this moment?
What do you think about this version of the app compared with the one(s) you used previously?
What is like when you are logging experiences as colours?
Did you ever look at the colours on your phone's display?

Interview B (day 42)

General questions

So, tell me how its been these last few weeks?
Do you feel like you have found a good way to use these apps?
Is there a structure to the way you use them?
Do you use the different apps in different ways at different times? How? Is there one app that you preferred?
Do you define a topic when you use it? Why? Why not? For all the apps or just one or 2 of them?

Second-person interview method questions

Ok I'd like you to talk me through an example of how you used the apps. To do this we need to try and get a sense of where you were and what you were doing first of all. This can help us to recall what the experience was like.
So Describe some of the things that you could see? Hear? Who was around?
What was happening in this particular moment? Ok so you ate doing x… then what happens?

Appendix IV: Experience sampling question sets

Set A – Logging a Colour

A1) You just logged colour. Where were you when you logged it?

At home
At work
Out and about
Other
Skip this question

A2) Who was around?

People I know
People I don't know
Nobody
Skip this question

A3) Why did you choose to log at this exact moment?

It was the moment when the experience happened
I waited for a convenient time to use the app
Because I was alone
The app caught my attention
Other
Skip this question

A4) How easy/difficult was it to log colour in this situation?

Easy
OK
Difficult
Skip this question

A5) Why did you choose this colour?

The colour fits the experience I wanted to log
The colour caught my attention
I like this colour
Other
Skip this question

A6) Did using the app make you question the way you think about something?

Yes
No
I'm not sure
Skip this question

A7) At what point did this happen? (Only asked If response to A6 is yes)

Before I thought about logging it
When I thought of using the app
When I chose colour in my mind
While I was selecting the colour in the pp
after I finished using the app
Other
Skip this question

A8) How did you feel when logging the colour?

Describe below
Skip this question

B - Inactivity

B1) You haven't used the app in the last few days. Is there any particular reason for this?

I forgot about it
I don't like using it
I haven't had the opportunity to use it
It's too difficult to use
Other
Skip this question

B2) Any other feedback or thoughts?

No options – open text

C – Topic setting

C1) You just set a new topic. Why?
I want a topic that matters to me
To make small change to the wording of the topic
The previous topic didn't work for me
Other
Skip this question

C2) Any other feedback or thoughts?

No options – open text

D Changing pre-set colours

D1) You just changed your pre-set colours. Why was this?
These colours are better for my topic
I want different colours on my phone's background
I want to try something new
Other
Skip this question

D2) Any other feedback or thoughts?

No options – open text

E - Comparing logging methods (weeks 1-3)

E1 How does the version of the pp you are now using compare with the last one you tried?

Worse
Similar
Better
Skip this question

E2 Any other feedback or thoughts?

No options – open text

F - Comparing logging methods (weeks 4-6)

F1) Why did you choose to use this app version to log the colour?

The other ones wouldn't work for this type of experience
This one is set up for the relevant topic
I prefer this one
Other
Skip this question

F2) Any other feedback or thoughts?

No options – open text

Appendix V: Chapter 5 – Interview excerpts in which participants described instances when they logged data and associated a meaning with it

P1

Logging Method	Excerpt
Capture	So I think I was listening to music through youtube. They were classical pieces, both of them. And I've never thought about an emotion while listening to these pieces. This music is quite complex. Other pop or rock songs, which have 4 chords and a continuous rhythm it's very obvious what emotion it's trying to convey. But when I was listening to these classical pieces of music, it was like oh, ok, I wonder how these pieces might actually be translated into a specific colour. Which colour is it?
Large palette	I had some experiences with coding. I experienced some really high and low points with the coding. I had some really great breakthroughs after two years of programming and they were really bright colours, oranges, light blues. But I was also struggling with some things and those were mainly greys and blacks.
Large palette	There were also some emotional things in terms of my relationships with people. I was a bit upset with what was going on and they were dark blues. And when I had nice experiences with people I recorded bright, happy colours, warm colours.
Large palette	It's hard. I know that I have been struggling a bit with some elements of my code and those things were blacks.
Pre-set palette	the colours have been mostly bright and nice colours… hmmm…. Ah…. yes…I was in London this weekend. I remember recording some nice colours. I went out for a walk with my sister and I recorded some colours.
All	This was when the code was going well (points at pink circle).
All	This is where it stopped working. It was like, "*I don't know what I'm doing, I'm yellow*." (points at dark yellow circle).
All	And this is Thursday, when I was supposed to submit it (points at a brown colour
All	). And this is Friday, this is when my code started to work actually (A light pale blue circle) … I told you that I prefer logging with the picker palette. But I'd chosen this one on Friday, probably because it was faster. So I knew the colour and probably I was too excited at that time (that his code worked) and I was like ok. I will just pick this one here.
All	Yes. (laughs), this one. I've been stressing a little bit because I have to prepare my place for leaving and pack everything. And the thing is, for example, I couldn't do anything at the weekend, because it's been a crazy weekend.

P2

Capture	It's just horrible and grey and miserable. So those are the colours that are on there. I put on it that we went to Levens and it was absolutely gorgeous. So we've got the blues and the yellows.
Capture	For one of them, the sky was sooo blue. I thought I wonder if I take this it will come up as blue. And it came up as the perfect blue of the sky
Capture	And those colours are a tree, a plant and the sky… And I thought that was really good…. Because it was just beautiful and it made me happy. And I thought, we're not gonna see many more of these this year… This colour blue.
Capture	Well, once the colours were on the back of my phone I thought, woah that's when we were at Levens and it was really nice…. In Levens I logged the colour because it was just, so lovely. The tree leaves were all changing colour. I was trying to get something to show this. But I'm not sure if I did. Were there any oranges on there? It was all the things that I like to look at.
Capture	Yesterday when it was grey and horrible and I was doing some emulsioning, it was nowhere near as nice. So I suppose those colours are matching what you're thinking aren't they. I picked those greys…
Capture	The blue was exactly the same colour as the sky that day. It was lovely.
Large palette	there was one when I was painting at Laurens. A lot of them were the colours that she was using (for the painting). I'm associating it always with things that I'm doing rather than what I'm feeling I think. So the colour of the paint and this kind of thing.
Large palette	Yeah there was, I think that was when I'd think, oh! This is really nice and then I'd look for a colour. Once it was really cold and so I was looking for a really icy blue. So they were attached to what I was doing again
Large palette	I did grey again when I was ironing. Because it's boring.
Pre-set palette	Last night it was cold and freezing and I was sat by the fire and I would just do all the fire colours.. yellows, reds and oranges. It was lovely. Because it was freezing outside last night. It was minus something. They were all cosy, warm colours, I thought.
Pre-set palette	We went to see the fireworks. I've probably put lots of blues and other colours for the fireworks.
All	The one where you take the picture. That one (points at phone). I think I took my Christmas cake and I was thinking look at how good that's come out. Well, it's brownish.
All	I tell you though one day, I was really sick. I felt awful because I felt rubbish. I think it was a yellowy one…. it was just a sickly, horrible colour. I just felt horrible. I really did.
All	That's what the green was! We were up Warton Cragg. And I think I was taking some of the holly leaves. And the colours are really really close to what you look at. We were at Warton Cragg and it was gorgeous, and I thought right, I'm gonna take one of these.

P3

Large palette	I did a very bright green for the wedding, and then did slightly paler greens for the rest of the week.
All	It was only odd occasions when there was something particularly… like a family event, or something else I'd been to, when I'd go, oh! Well that was a bright green day. But at the same time, I've probably drifted into a yellow, once.
All	Ermm… I think. I guess I had a long day travelling…. I'd been away for a while and when I got back... I was on my way from Bosnia… I was quite hungover… And then when I got back I had quite a full-on discussion with P4 about something that wasn't that fun.

P4

Capture	I was putting colours on my screen that I liked. But then there was a day, when I was really, really tired. And I hadn't felt well at all. And so I changed the whole screen because it was too bright.
All	Yesterday I logged a darker red, because I had a really bad session on her and I actually came off! We didn't have a good session at al. Yesterday when I fell off, I didn't go for the worst one, because there were some good points from the session. But it wasn't ideal.
All	But then the rest of the week has been really positive and like, a nice brighter green. I never went for the best green. But one down from the best one. So it was positive.
All	I would just take any colour in the room that I thought was nice

P5

Large palette	Perhaps yellow. I think I used that for positive events. It was at the weekend and it was a nice sunny day.
Large palette	I think there was a day when I finished work on time, I was in a good mood and I went to the gym. I logged an orange colour
Large palette	A greeny one when I was stressed out with work.
All	So, one Sunday I had a quite a chilled day and I was feeling quite positive. So I think it was probably these. It was quite a quiet day… And I just had a minute. So, yeah those are ones I can remember.

P6

Large palette	I had a quite a chilled kind of day and so I picked bright yellow. That was one of the only ones where I could think of a colour…. I think I just saw the yellow. There were some yellow flowers and I thought ohhh, they're nice and so I noticed the yellow flowers. And then I realized that I'd had quite a nice day because I hadn't thought about work all day. And so I think I just associated the colour yellow with relaxed and happy.
Large palette	last week I did loads of paper work. I was sorting out finances and stuff. And I was surrounded by paper. I picked white because it was the colour of paper. But honestly, I was just looking at it and I was like, what should I pick and I was like, this colour represents my day, because I was surrounded by paper all day.
All	Red was if I felt overall negative about the day. It was a bit like traffic lights. Yellow was it if it has been alright and green was good. Obviously it's been the weekend so the colour is green
All	One of them was when I went for a walk and I took a picture of a flower. And that was really nice. But more often it was like, oh! I'd better take a picture. And then I would just take one that I hadn't picked for a while.
All	Ok. Well that one there was when I was fuming at work. I was just fuming about the Tories, about budget cuts, about how much we have to teach and I just left early from work.

P7

Large palette	The red, which is the last time I used it, was on Wednesday, when (her husband) had lost his passport and he wasn't coming home and I was feeling really angry. I was feeling cross and so... But I don't know what prompted me to do it. Maybe because I had an extreme emotion.
Large palette	I think I did that pale blue when I went to cottage with my friends. We were really relaxed and we had little fire. I was feeling really Zen. So I think I did those pale colours.
Pre-set palette	I can remember one. Like I chose all the… I think it was last Monday. I hadn't had good day at work and everything was too much. And I think all my colours were like blacks and greys. I reset all of them to blacks and greys. It was maybe because I saw lots of bright colours on my screen and I thought this is not how I'm feeling!
Capture	I was putting the Christmas tree up. And I was trying to capture one of the gold baubles. And so I was all Christmassy and nice and festive and happy… I was trying to capture some gold, shiny something.
Capture	The latest one was when I was at my Mum and Dad's and I was all snug in front of the fire and I captured the purple of the cushions.
All	I think I was tired because it was Thursday. But it's nearly the weekend. I'm hearing a lot of talk about it being miserable because it's January. But I chose the blue because I feel quite excited about the year ahead. So it's blue, I'm tired, looking forwards to the weekend, but actually quite happy.

P8

Capture	Overall this week has been very tough. On Friday I had a mock driving test. I think I did a few reds at that time. I can't quite remember how I reacted. Otherwise, if I couldn't find a red, I'd just do a few blacks.
Capture	. I think the only positive experience I could log was yesterday, when it was very nice and sunny in the morning when I went out
Capture	maybe there was another time when I felt good when I woke up and I logged a green. Otherwise it was a week where it's either black or shades of red.
Capture	Man Utd lost. That was red. I did a shade of red because… hmmm.. where did I get the shade of red from. We were on the move… Hold on… I think we went out for lunch. I don't think I could find a red at that time and perhaps I had to wait and log it later. I can't recall exactly.
Large palette	Well for example after I passed my test. I think it was the most ermm. Well I didn't go for the most sharp green. But. It was the most pleasant green. At that time I was feeling quite relieved.

P9

Large palette	And I think the darker ones I was in quite a bad mood. I had got no work done. And then I cheered up a bit.
Large palette	I realised that I was going for really bright colours. Like pastel, bright colours. I think that may have also been affected by… because I was travelling and I always sit on the bus. And if it's like a clear sky, I guess it puts me in a good mood.
Pre-set palette	Initially, I set it up with all bright colours because they are my favourite colours. But because they are all nice colours, if I wasn't feeling so good, I would go in an change them all. So now I have quite a wide range.
Pre-set palette	If I was in a good mood, I would look for colours that were brighter, ones that I found appealing.
Capture	Yeah, I was already using my phone. And I saw the background. In that instance it wasn't to match the colours on my phone…. I think in this particular week, I would look around the room to see what kind of colours I had in my room. And then I'd try find the colour that would fit from what I could see in my room. So, the colours were a lot more limited. I've been self-isolating so there wasn't very much… colour. I did notice when I was logging the colours that my room was quote dull and I would see if anything just popped out. And that was usually what I'd log. The contrast was important.
Capture	There was an event where it really made me happy. I had a great time with a friend and I was in a really good mood. And I thought, you know what, I'll log a colour. (In week Capture)
All	So this bright orange light just fills our room. And I think it's really pretty and I want to take a picture of it and remember it somehow. And I've got this handy little app, which I can use to take its colour. There are a few examples like that. There's the sunset, the sea as well. They're just things that I like to look at. And I just end up getting the colours for them.

P10

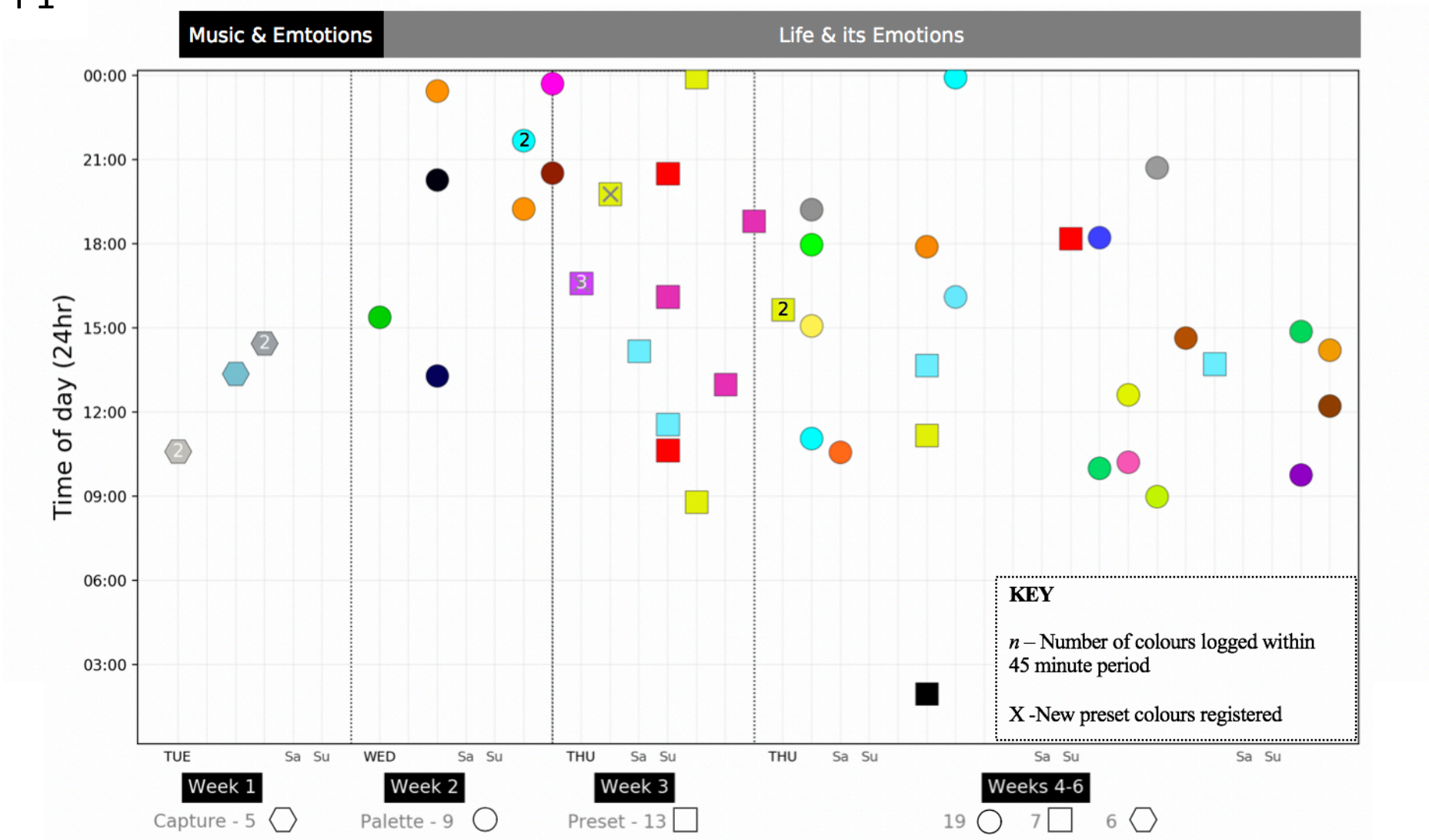
Capture	So I was logging colours for social interactions. but I found that as time went on, I was logging the feeling about those interactions. if I'd had a bad social experience with someone and I'd used a black colour, that colour would remind me of the conversation
Capture	if I'd been to the pool, I'd take a blue colour.
Capture	If I was with someone and it was a really meaningful conversation I would log a colour from that conversation. Like, for example, I remember taking the colour of their t shirt.
Large palette	I picked a blue because In was singing at church because that was the colour of the cassocks. And I liked that I could find that exact blue.
Pre-set palette	Yeah, it was. So I went to the zoo and I created a pattern that was for a zebra and for a giraffe. And if something made me feel a certain colour. I would choose a colour and then choose the other colours that went around it.
Pre-set palette	I think that when lockdown was introduced, I put all black!
All	I'd been interacting with the same people all the time (referring to coronavirus lockdown). So it was more sort of, the mood of the day. Or if something happened. I remember logging yellow at Easter
All	I think kind of, having a strong emotion or feeling, a bit more than an ordinary feeling. Or if a particular event had happened in the day. I remember playing a board game with my family and that was a nice experience. I logged that. It was when things happened rather than nothing (during the Covid lockdown, Large palette)
All	Really, it's how I'm feeling. So the bright colours I chose, were bright luminous colours. But then again, it was how they went together as well. One day I chose lots of, like, highlighter colours, and that was for a day that was sort of out of the mundane.
All	Well, there were times when I did just choose white and black. They were just when I was not feeling anything
All	I think I did use the camera one. I'd been in my dressing gown, like endlessly and I wanted to take a picture of that. It was a very sunny day and I think I made a gradient of the dressing gown.

P11

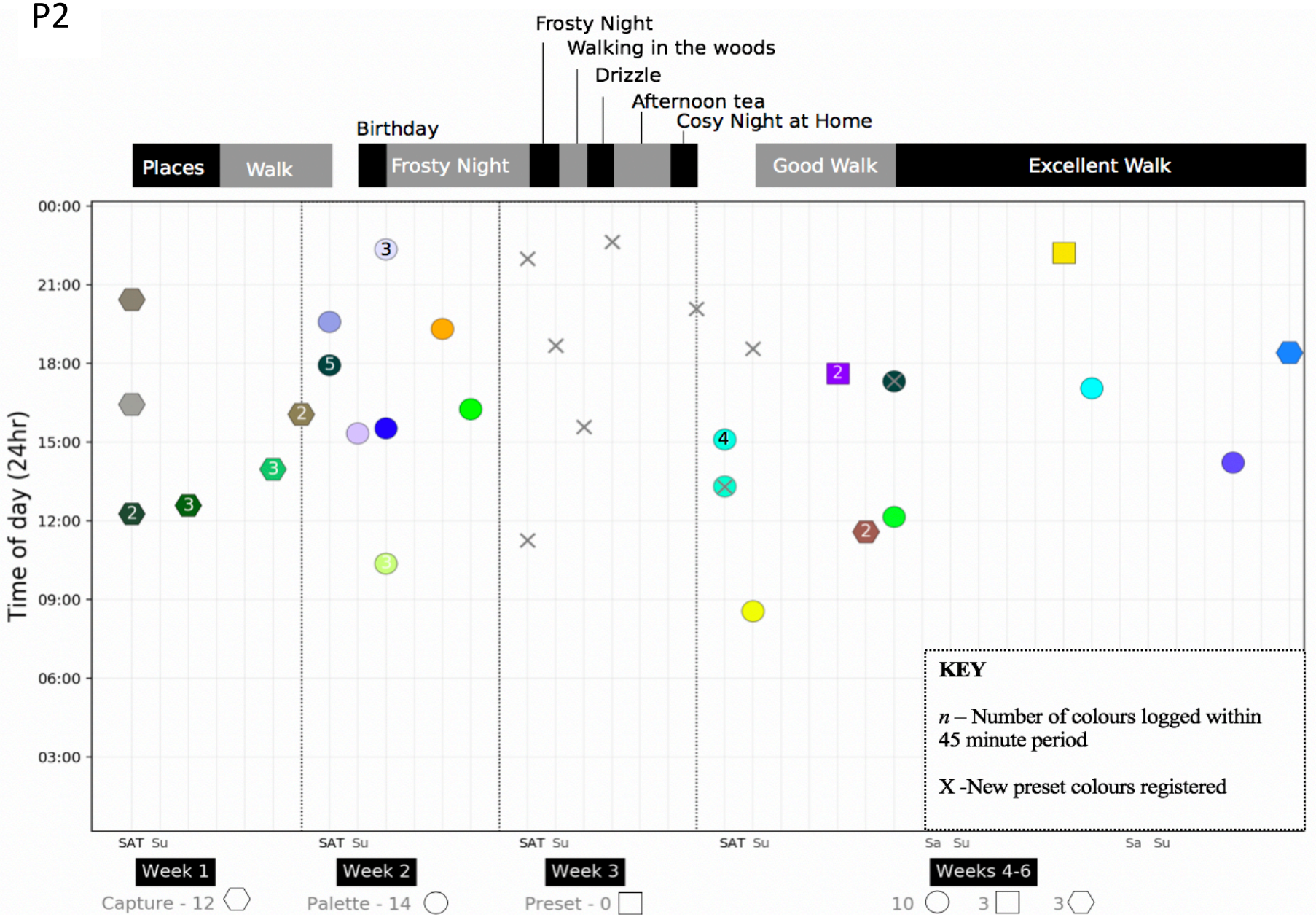
Large palette	So, I think… off the top of my head…At the minute I've put one on which was to do with the weather because it was rather wet and miserable….
Large palette	I was definitely on the journey home [from work]. I was looking forwards to being in the warmth…. Or I had just got warm and I was trying to explore another topic
Large palette	More recently what I was doing, like with the weather, was logging what was actually happening rather than reflecting quite as much. It was the same with warmth and cosiness. And I think I'm finding that more meaningful, to capture the experience as it is happening, rather than reflecting backwards. Because then, obviously the data that is collected, you can look back on it…. I put on a sort of warmish colour when I was talking about cosiness. I have a blanket which is an autumn, Bucannon blanket. So it's sort of an orange tone, with all different…. It's a great tartan. It was hues of the blanket.
All	that was the dog that I was coming back to… Or, the orange shade of ermm… a bottle of Christmas iron bru that we sell… It's called Crimbo juice.
All	I really like to eat. I do to a certain point like to cook and eat for pleasure. And that isn't something that I've been really conscious of before. But where I've started to pick up colours, like maybe from a label, like a vibrant red, to do with a tomato sauce
All	There was a really vibrant orange colour that I recorded once and that was a train ticket. It was really close to Christmas, it was a really, really long week; I'd been working hours and hours and hours. I'd just done like a two-hour shift and it was pitch black dark. There was no light and it was really gloomy and everything was sort of grim. But being sat on the train was such a warm and comfortable feeling. And I record the colour of the ticket and that put me in a totally different frame of mind.

Appendix VI: Chapter 5 – Participant logging timelines

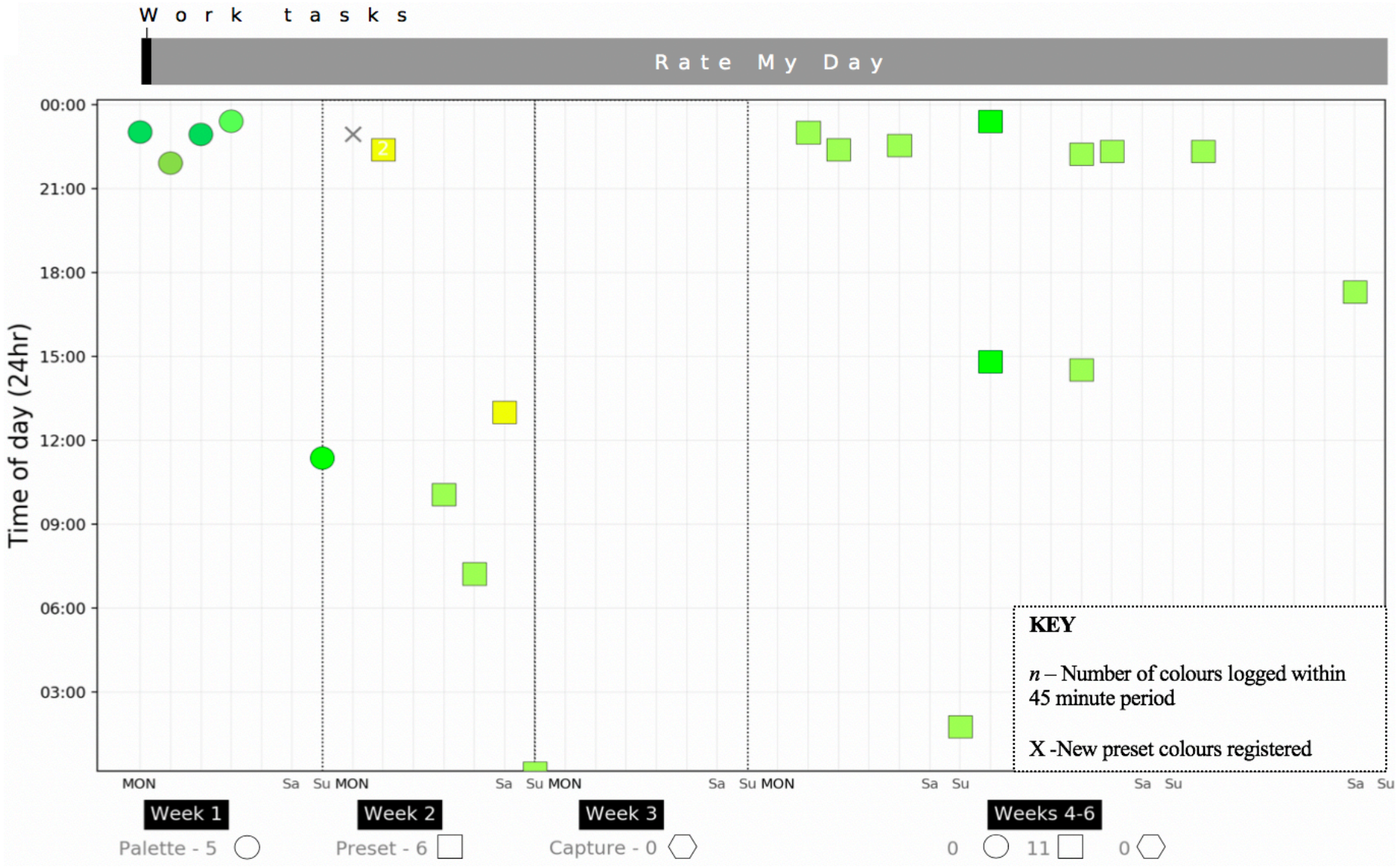
P1


Music & Emtotions
Life & its Emotions
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
TUE
Sa Su
WED
Sa Su
THU
Sa Su
THU
Sa Su
Sa Su
Sa Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Capture - 5
Week 2
Palette - 9
Week 3
Preset - 13
Weeks 4-6
19
7
6

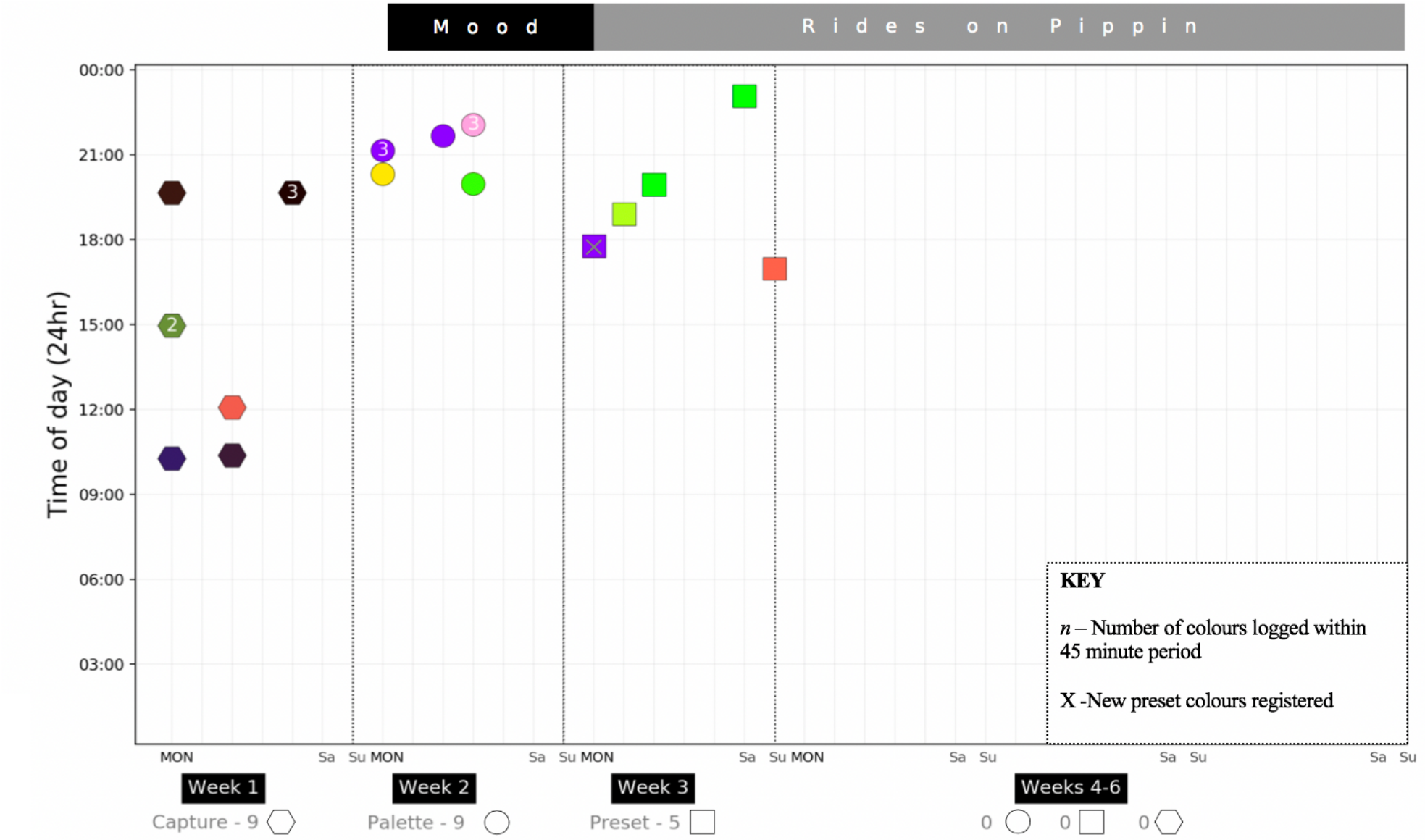
P2


Frosty Night
Walking in the woods
Drizzle
Afternoon tea
Cosy Night at Home
Birthday
Places
Walk
Frosty Night
Good Walk
Excellent Walk
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
SAT Su
SAT Su
SAT Su
SAT Su
Sa Su
Sa Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Capture - 12
Week 2
Palette - 14
Week 3
Preset - 0
Weeks 4-6
10
3
3

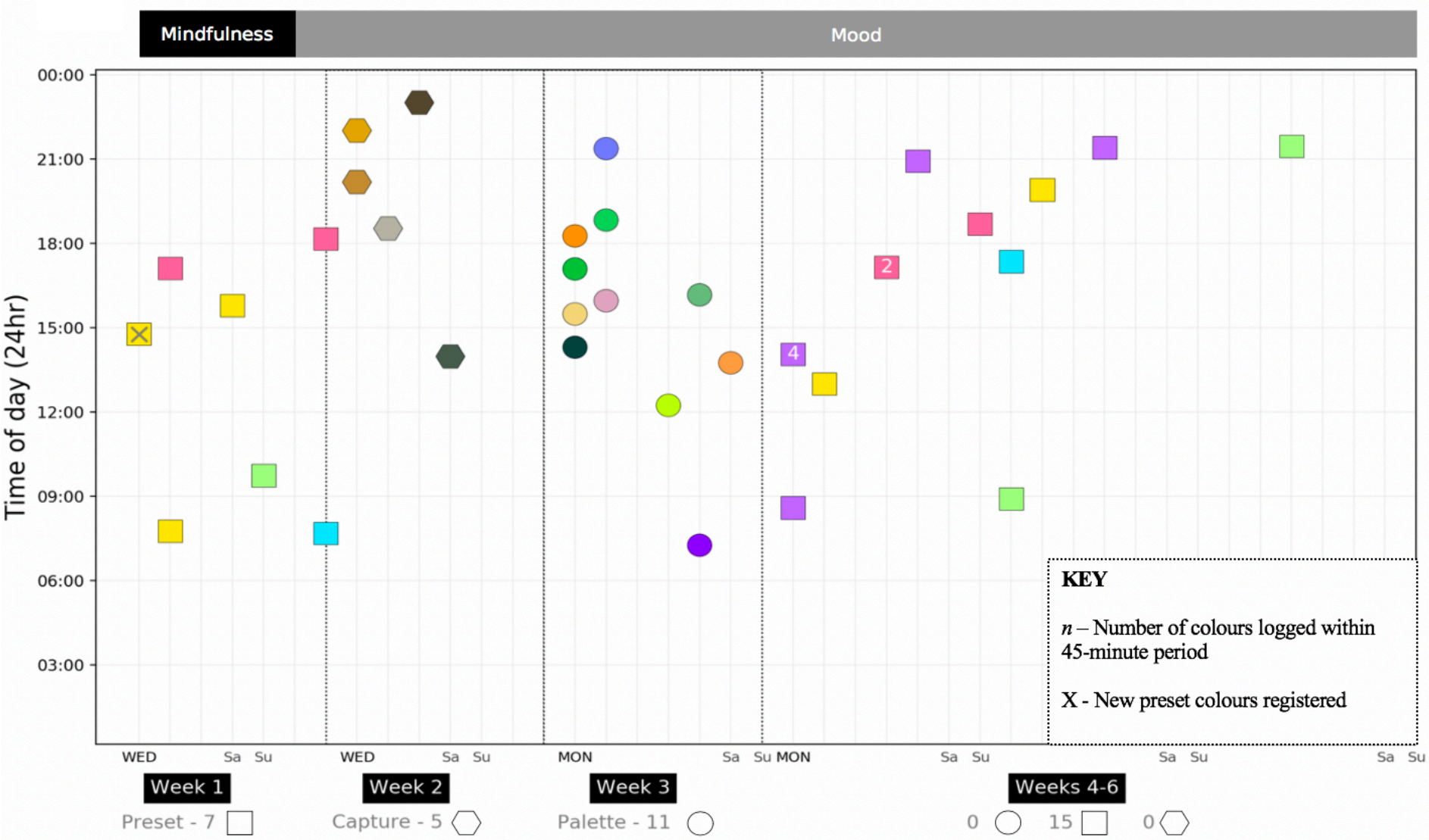
P3


Work tasks
Rate My Day
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
2
MON
Sa
Su
MON
Sa
Su
MON
Sa
Su
MON
Sa
Su
Sa
Su
Sa
Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Palette - 5
Week 2
Preset - 6
Week 3
Capture - 0
Weeks 4-6
0
11
0

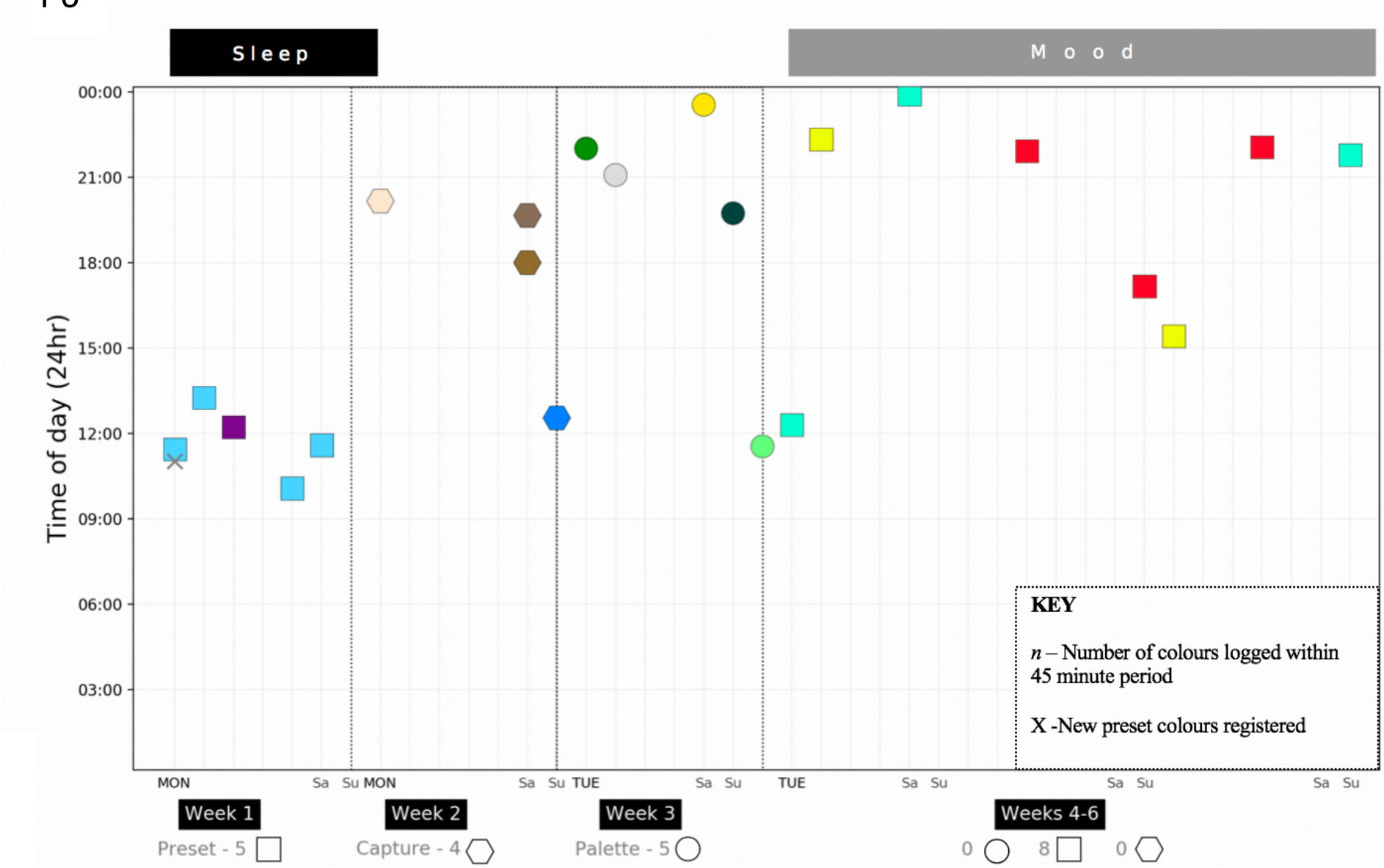
P4


Mood
Rides on Pippin
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
MON
Sa
Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Capture - 9
Week 2
Palette - 9
Week 3
Preset - 5
Weeks 4-6
0
0
0

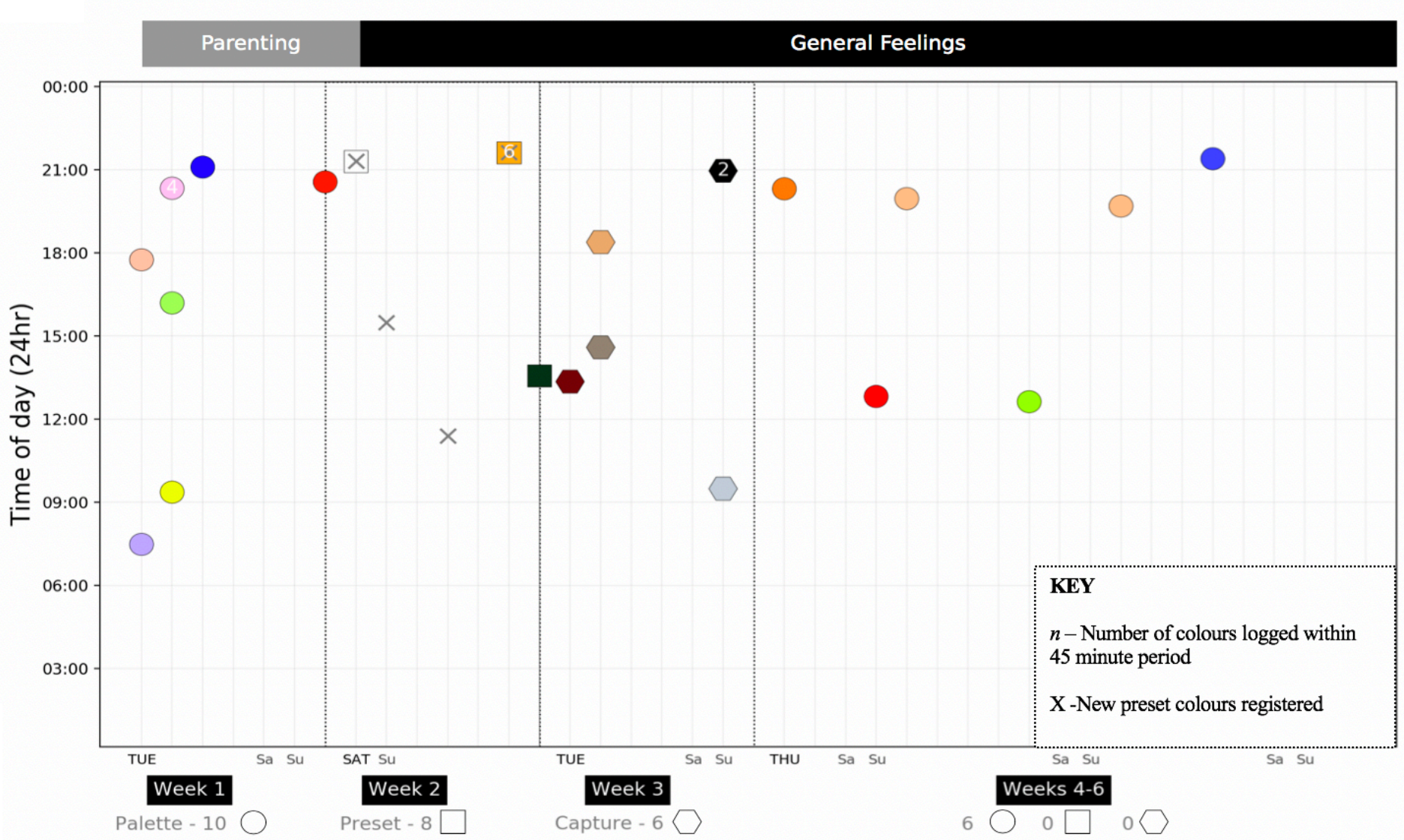
P5


Mindfulness
Mood
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
WED
Sa
Su
WED
Sa
Su
MON
Sa
Su
MON
Sa
Su
Sa
Su
Sa
Su
2
4
KEY
n – Number of colours logged within 45-minute period
X - New preset colours registered
Week 1
Preset - 7
Week 2
Capture - 5
Week 3
Palette - 11
Weeks 4-6
0
15
0

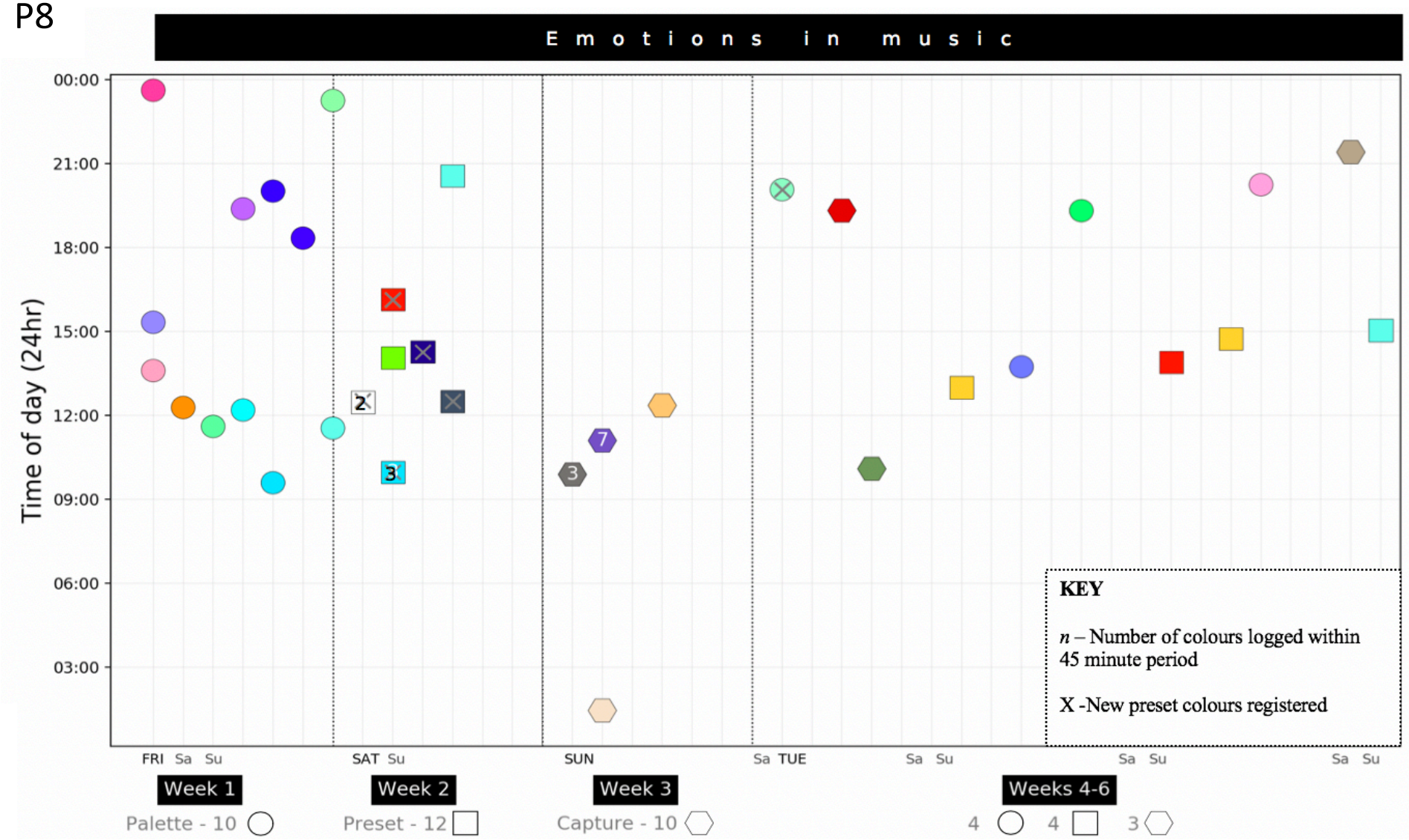
P6


Sleep
Mood
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
MON
Sa
Su
MON
Sa
Su
TUE
Sa
Su
TUE
Sa
Su
Sa
Su
Sa
Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Preset - 5
Week 2
Capture - 4
Week 3
Palette - 5
Weeks 4-6
0
8
0

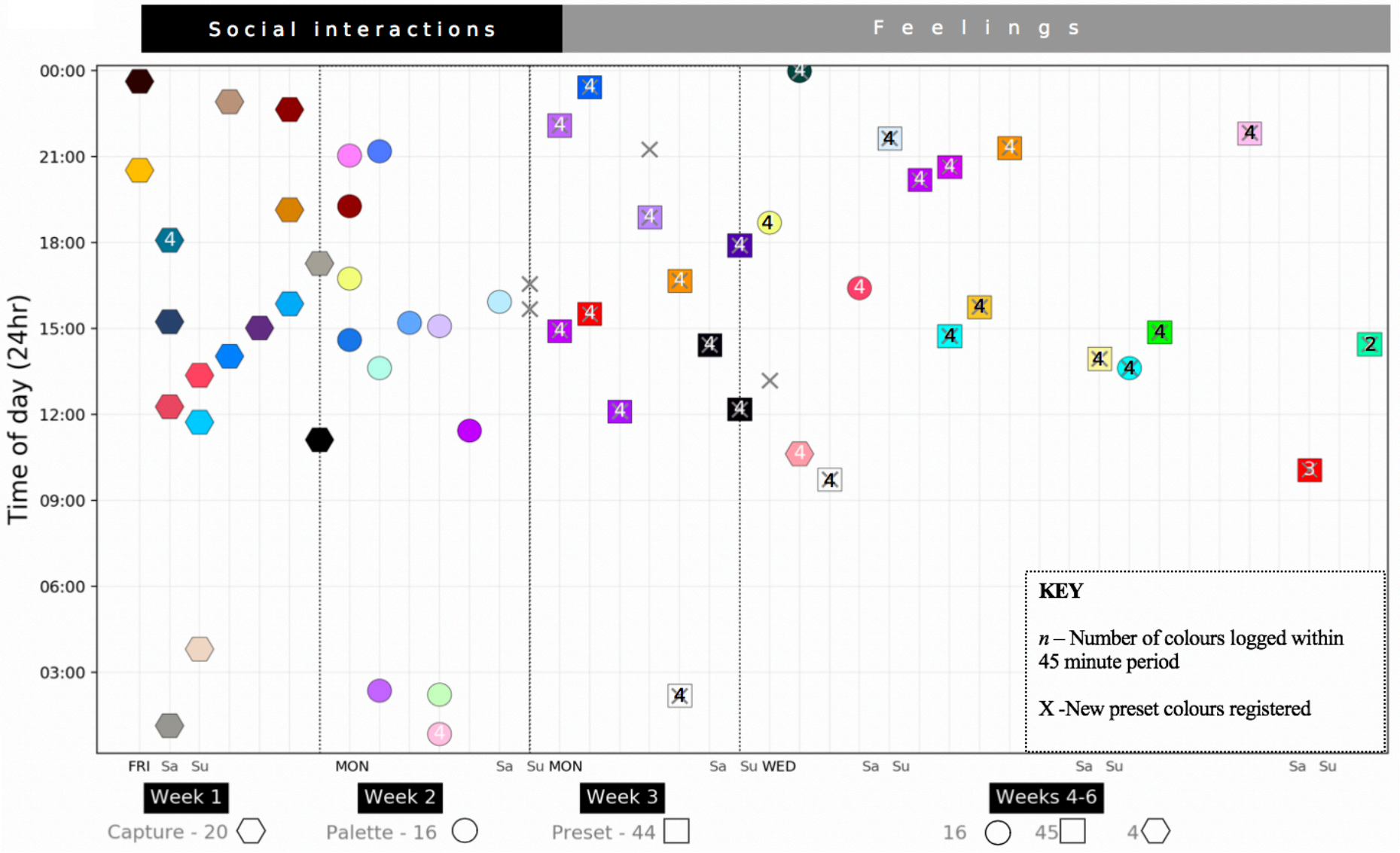
P7


Parenting
General Feelings
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
TUE
Sa
Su
SAT
Su
TUE
Sa
Su
THU
Sa
Su
Sa
Su
Sa
Su
Week 1
Palette - 10
Week 2
Preset - 8
Week 3
Capture - 6
Weeks 4-6
6
0
0
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered

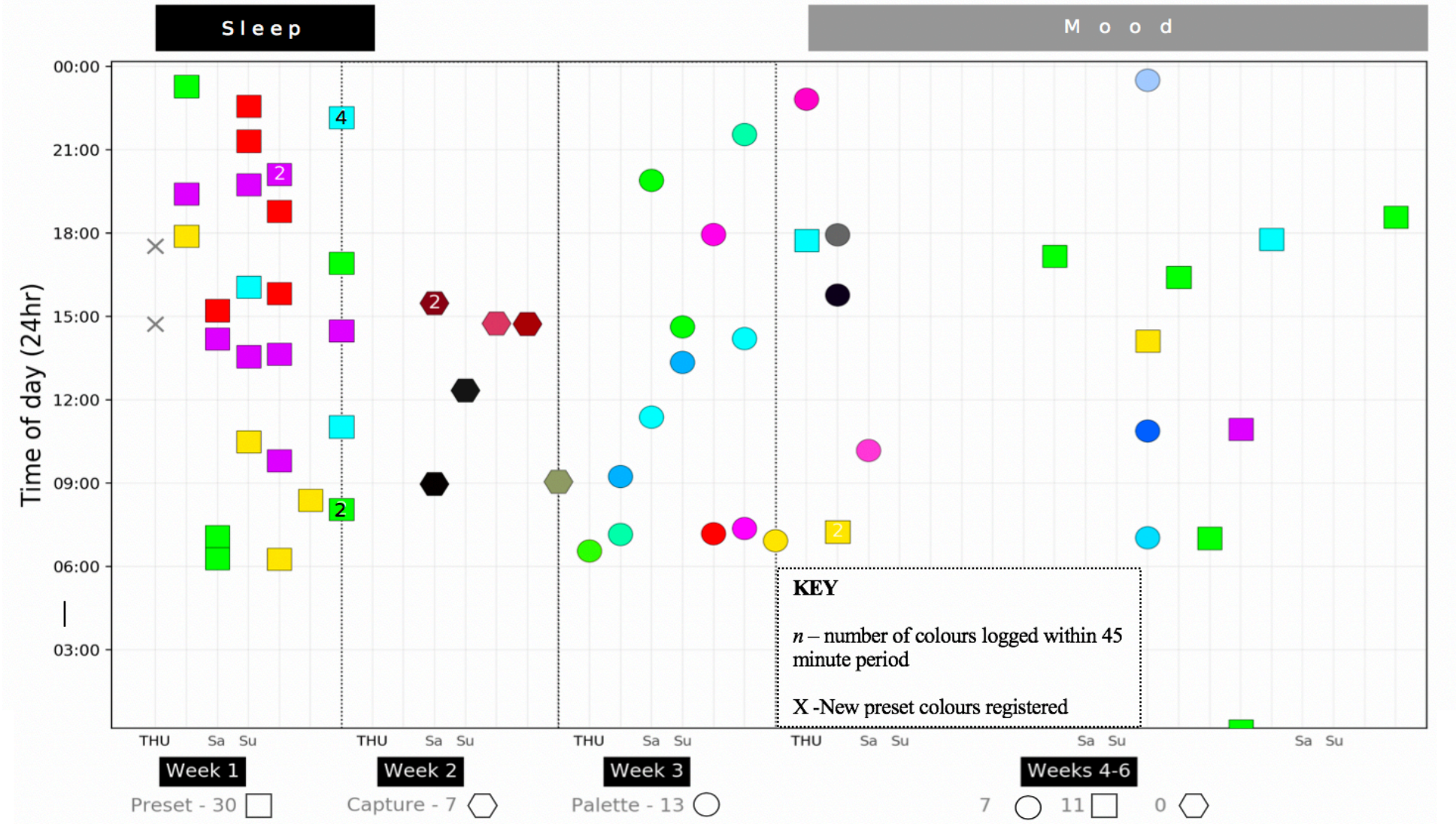
P8


Emotions in music
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
FRI Sa Su
SAT Su
SUN
Sa TUE
Sa Su
Sa Su
Sa Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Week 2
Week 3
Weeks 4-6
Palette - 10
Preset - 12
Capture - 10
4
4
3

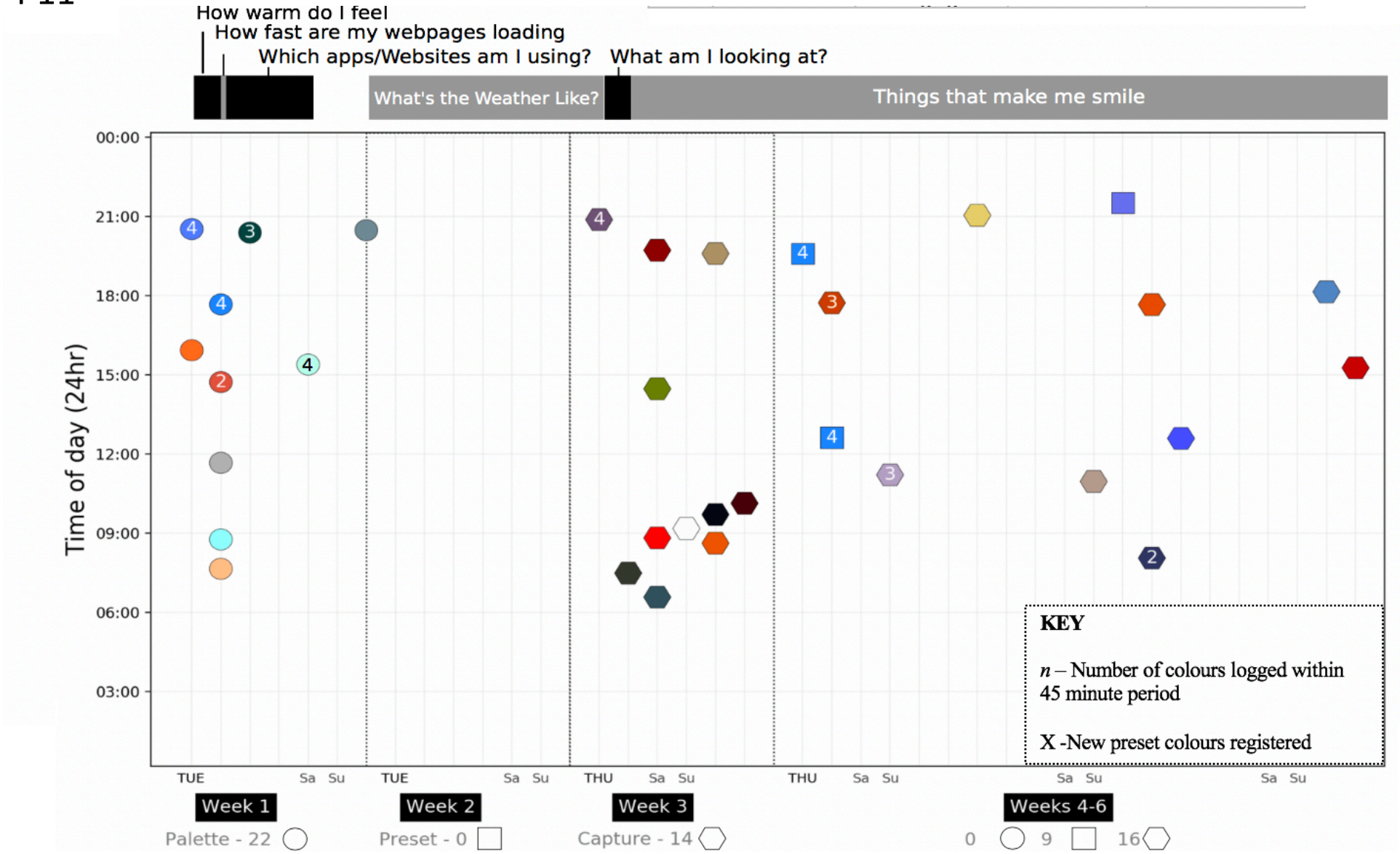
P9


Social interactions
Feelings
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
FRI Sa Su
MON
Sa Su MON
Sa Su WED
Sa Su
Sa Su
Sa Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Capture - 20
Week 2
Palette - 16
Week 3
Preset - 44
Weeks 4-6
16
45
4

P10


Sleep
Mood
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
THU Sa Su
Week 1
Week 2
Week 3
Weeks 4-6
KEY
n – number of colours logged within 45 minute period
X -New preset colours registered
Preset - 30
Capture - 7
Palette - 13
7
11
0

P11


How warm do I feel
How fast are my webpages loading
Which apps/Websites am I using?
What am I looking at?
What's the Weather Like?
Things that make me smile
Time of day (24hr)
00:00
21:00
18:00
15:00
12:00
09:00
06:00
03:00
TUE
Sa
Su
TUE
Sa
Su
THU
Sa
Su
THU
Sa
Su
Sa
Su
Sa
Su
KEY
n – Number of colours logged within 45 minute period
X -New preset colours registered
Week 1
Week 2
Week 3
Weeks 4-6
Palette - 22
Preset - 0
Capture - 14
0
9
16